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TESIS DOCTORAL

ANÁLISIS DE LAS DEMANDAS COMPETITIVAS DEL TENIS EN SILLA DE RUEDAS DE ALTO NIVEL

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AUTORIZACIÓN DE LOS DIRECTORES DE LA TESIS PARA SU PRESENTACIÓN

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1. **Sánchez-Pay, A**; Sanz-Rivas, D; Torres-Luque, G. (2015). Match analysis in a wheelchair tennis tournament. *International Journal of Performance Analysis in Sport, Press. Agosto 2015*.
2. **Sánchez-Pay, A**; Torres-Luque, G; Sanz-Rivas, D. Activity pattern in male and female wheelchair tennis tournament. Enviado a Kinesiology en Mayo de 2015.
3. **Sánchez-Pay, A**; Palao, J.M; Torres-Luque, G; Sanz-Rivas, D. Differences in set statistics between wheelchair tennis vs conventional tennis in different types of surface and gender. Enviado a Journal of Sports Sciences en Junio de 2015.
4. **Sánchez-Pay, A**; Torres-Luque, G; Cabello-Manrique, D; Sanz-Rivas, D; Palao, J.M. (2015). Match analysis of women´s wheelchair tennis matches for the Paralympic Games. *International Journal of Performance Analysis in Sport, 15*, 69-79.
5. **Sánchez-Pay, A**; Torres-Luque, G; Fernández-García, A. I.; Sanz-Rivas, D.; Palao, J.M. Differences in game statistics between winning and losing male wheelchair tennis players in 2012 Paralympics Games. Enviado a Journal of Human Kinetics en Junio de 2014.
6. **Sánchez-Pay, A**; Torres-Luque, G; Sanz-Rivas, D. (2015). Match activity and physiological load in wheelchair tennis players: a pilot study. *Spinal Cord.* Aceptado mayo de 2015.

RESUMEN

Los deportes adaptados surgen como medio de rehabilitación física e integración social para personas con discapacidad. El tenis en silla de ruedas (TSR) es uno de los deportes adaptados que más ha crecido en los últimos años y la orientación competitiva en dicho deporte ha ganado importancia. Los diversos estudios realizados en la última década sobre las demandas de la competición en el TSR han servido de guía para los entrenadores y preparadores físicos con el objetivo de mejorar los sistemas de entrenamiento, aunque hay escasa información sobre algunos aspectos del juego. El objetivo general de la tesis fue describir las demandas físicas, técnicas, tácticas y psicofisiológicas de la competición del TSR así como observar las diferencias entre género, superficie de juego y entre ganadores y perdedores.

Se grabaron partidos de TSR de categoría Open y nivel internacional tanto masculinos como femeninos para determinar la estructura temporal y observar las posibles diferencias entre género. Se registraron las estadísticas de competición de tres Grand Slam jugados en diferentes superficies para determinar las demandas físicas y técnicas en cada superficie y observar las posibles diferencias con el tenis convencional. De igual forma se registraron y analizaron las estadísticas de competición de los Juegos Paralímpicos de Londres 2012 para comparar las diferencias entre ganadores y perdedores tanto en jugadores masculinos como femeninas. A su vez, se colocaron pulsómetros para monitorizar la frecuencia cardiaca (FC), se tomaron muestras de lactato sanguíneo (LA), y se determinó la percepción subjetiva de esfuerzo (RPE) durante el partido. Para el visionado y codificación de los datos se realizó un entrenamiento de observadores controlando el análisis inter e intra observador a través del test Cohen's Kappa. La prueba U de Mann-Whitney fue utilizada para observar las diferencias estadísticas entre superficies y género, el test de Wilcoxon para analizar las diferencias entre ganadores y perdedores así como comparar el patrón de juego en situaciones de break o no.

Los resultados más significativos de la Tesis muestran que: a) un partido de TSR dura en torno a 61 minutos con un tiempo real de juego del 20%, mostrando una relación de tiempo de trabajo : tiempo de descanso de 1:4 y una duración media del punto de 6.9 segundos con 3 golpes por punto; b) la duración del punto, número de botes por punto y ritmo de juego varían entre género; c) la superficie de la pista tiene una incidencia directa con las demandas físicas y técnicas de los jugadores, tanto a nivel

masculino como femenino; d) los ganadores del partido tienen mejor efectividad que los perdedores tanto en la situación de saque como en la situación de resto, donde las variables que mejor diferencian el rendimiento son los puntos de break ganados y los puntos ganados de primer saque; y, e) las demandas psicofisiológicas durante los partidos son de 124 lat·min^{-1}, 66.31 %FC_{max}, 1.41 mmol·L^{-1} en concentración de lactato y 12.45 en la escala RPE, dónde la acción de saque o resto no produce diferencias en las respuestas de LA o RPE.

ABSTRACT

Adapted Sports were created to foster physical rehabilitation and social inclusion for people with disabilities. Wheelchair tennis (WT) is one of the adapted sports that has grown the most in recent years, and the sport's competitive orientation has gained importance. Some studies about the competitive demands of WT have served as guides for coaches and trainers to improve training systems, although there is a lack of information regarding some aspects of the game. The global aim of the thesis was to describe the physical, technical, tactical, and psychophysiological demands of WT competition and to observe the differences between gender, surfaces, and between winners and losers.

International WT matches of male and female players were filmed with the aim of assessing players' activity patterns as well as the differences between genders. Further, match statistics of three Grand Slams played on different surfaces were collected to evaluate the physical and technical demands of each surface and determine differences between WT and conventional tennis (CT). Data from the 2012 London Paralympic Games were collected and subsequently analysed to assess the differences between winning and losing players in men's and women's matches. Moreover, activity patterns, HR, blood lactate concentration (LA), and ratings of perceived exertion (RPE) were measured during a national WT team stage. For the viewing and coding of matches, observer training was carried out. Intra- and inter-rater reliability were calculated, and Cohen's Kappa was used. The Mann-Whitney U test was utilised to observe statistical differences between surfaces and gender, while the Wilcoxon test was utilised to analyse the differences between winners and losers and to compare activity patterns in situations that were or were not break situations.

The most significant results of the thesis regarding WTshow that: a) the length of the WT match is around 61 minutes, with an effective playing time of 20%, resulting in a ratio of work time: rest time of 1:4 and a rally duration of approximately 6.9 seconds, with 3 shots per point; b) the rally duration, the number of bounces per point, and the rhythm of play are different in men's and women's matches; c) the playing surface affects the players' physical and technical demands for both genders; d) winning players have better effectiveness than losing players both for the serve and the return situation, and the variables that best differentiate their performances are break points won and points won on first service; and, e) the physiological load during the matches

involves 124.25 b·min^{1}, 66.31 %HR_{max}, 1.41 mmol L^{-1} and 12.45 on the RPE scale, and the serve and return situations do not produce different responses in LA or RPE.

ABREVIATURAS

TC	Tenis convencional
TSR	Tenis en silla de ruedas
FC	Frecuencia cardiaca
LA	Concentración de lactato sanguíneo
RPE	Percepción subjetiva del esfuerzo
CT	Conventional tennis
WT	Wheelchair tennis
ITF	International tennis federation
RD	Rally duration
TT	Total match time
EPT	Effective playing time
TRT	Total rest time
RTP	Resting time between points
W:R	Working time : resting time ratio
SR	Shots per rally
PG	Point per game
PS	Point per set
PM	Point per match
BO	Break point opportunity
NBO	Non break point opportunity
AO	Australian Open
RG	Roland Garros
UO	US Open
HR	Heart rate
HR_{ma}	Maximal heart rate
VO_{2ma}	Maximal oxygen uptake
LA	Blood lactate concentration
RPE	Rate of perceived exertion
M	Mean
SD	Standard deviation
SCI	Spinal cord injury

INTRODUCCIÓN

El tenis convencional (TC) es uno de los deportes más practicados a nivel mundial, y el primero de los considerados deportes de raqueta (García Ferrando & Llopis, 2011). El deporte fue adaptado para poder ser practicado por personas con alguna discapacidad física. Así fue como se desarrolló el tenis en silla de ruedas (TSR) a finales de los años 80 en Estados Unidos. Su impulsor fue Brad Parks, un deportista norteamericano que tras un accidente conoció a Jeff Minnenbraker y juntos comenzaron la promoción del deporte a través de clínics, exhibiciones y torneos por América (Sanz, 2003). El TSR tuvo su inclusión como deporte paralímpico en los juegos de Barcelona 92 y en la actualidad existen más de 150 torneos internacionales repartidos por más de 40 países (Bullock & Sanz, 2010).

El TSR es siempre jugado sobre una silla de ruedas. Los jugadores utilizan la silla para desplazarse por la pista impulsando las ruedas con los brazos, o a través del uso de sillas eléctricas. La utilización de una u otra silla dependerá de la movilidad funcional del jugador. Debido al gran abanico de lesiones de los jugadores participantes cuya movilidad funcional se verá afectada, la Federación Internacional de Tenis (ITF) tiene reconocidas dos categorías en función de la limitación funcional del jugador (Quad y Open). En la categoría Quad juegan los tenistas que tienen una gran limitación funcional como consecuencia de una lesión severa (ej. cuadriplejia). Por el contrario, en la categoría Open se encuentran los jugadores con una limitación funcional baja (lesión medular baja, amputados, poliomielitis, etc.). La limitación funcional parece tener relación directa con diversos parámetros del juego tales como velocidad (Goosey-Tolfrey & Moss, 2005), cantidad de desplazamiento (Filipčič & Filipčič, 2009a; Sindall et al., 2013), etc. Independientemente del tipo de lesión y la categoría en la que juegue el tenista, las reglas son idénticas para todos; y están basadas por el reglamento de la ITF siendo la principal diferencia respecto al TC de que la pelota pueda botar dos veces antes de ser golpeada (ITF, 2012).

El TSR es siempre jugado al mejor de tres tie-break sets, a diferencia del TC que en algunos torneos es jugado al mejor de cinco sets (ITF, 2012). De forma general, el tiempo total de juego de un partido de tenis en silla de ruedas de individuales se encuentra entre los 50 y 80 minutos (Croft et al., 2010; Filipčič & Filipčič, 2009b; Roy et al., 2006; Sanz et al., 2009; Sindall et al., 2013); si bien, la duración del mismo pueden venir determinado en función del nivel de los participantes o tipo de lesión entre

otras (Filipčič & Filipčič, 2006, 2009b; Sindall et al., 2013). Durante el partido, los jugadores tienen un tiempo máximo entre puntos de 20 segundos y de 90 entre cambios de campo (ITF, 2012). El tiempo total de descanso en un partido de individuales de TSR se encuentra entre el 80-85% del tiempo total, por lo que el jugador está golpeando la pelota alrededor del 15-20%, lo que equivale a un ratio tiempo de trabajo/tiempo de descanso aproximado de 1:4 (Filipčič & Filipčič, 2009b; Roy et al., 2006; Sanz et al., 2009). El tiempo de trabajo es la suma total de la duración de todos los puntos. En este sentido, la duración media de un peloteo se sitúa entre 4 y 10 segundos (Bullock & Pluim, 2003; Filipčič & Filipčič, 2009b; Veltmeijer et al., 2014). Durante la duración del punto, el jugador golpea la pelota entre 2 y 4 veces (Bullock & Pluim, 2003; Filipčič & Filipčič, 2009b; Veltmeijer et al., 2014). Este gran rango de valores (superior al 100% en muchos de los parámetros) puede ser debido a las características de la muestra de cada uno de los estudios, a nivel de tipo de lesión o nivel competitivo de los jugadores. Ningún estudio ha evaluado la estructura temporal y el patrón de juego del TSR de forma conjunta. Su conocimiento ayudaría a los entrenadores y preparadores físicos a diseñar ejercicios acorde a las demandas de la competición, teniendo en cuenta aspectos relacionados con duración de los ejercicios, duración de los descansos, número de repeticiones, número de series, etc.

La competición de TSR masculina es independiente de la femenina en categoría Open. Sólo la categoría Quad se juega de forma mixta. Las características físicas de los jugadores (chicos y chicas) pueden hacer que las demandas de la competición sean diferentes. En el TC se han encontrado diferencias en el patrón de juego (Brown & O'Donoghue, 2008; O'Donoghue & Ingram, 2001), por lo que los sistemas de entrenamiento deben ser adaptados por género. Todos los estudios en TRS en relación al patrón de juego han sido realizados en jugadores masculinos, no teniéndose información en género femenino.

El TSR puede ser jugado en diferentes tipos de superficie (hierba, tierra batida o pista dura) y tiene presencia en los cuatro torneos de Grand Slam (Abierto de Australia, Roland Garros, Wimbledon y Abierto de los EEUU) (Sánchez-Pay, Torres-Luque, & Sanz-Rivas, 2014). La superficie de juego puede tener una influencia directa sobre diversos parámetros del juego y del propio jugador. Esta influencia ha sido ampliamente estudiada en el TC observándose diferencias en la duración de los peloteos y número de golpeos (O'Donoghue & Ingram, 2001), estadísticas de rendimiento (Barnett, Meyer, &

Pollard, 2008; Cross & Pollard, 2009; Katić et al., 2011), incluso se han observado diferencias entre en ambos géneros (Brown & O'Donoghue, 2008; Filipčič, Filipčič, & Berendijaš, 2009; O'Donoghue, 2002). Conocer las características de la competición en cada una de las superficies ayuda a preparar específicamente cada uno de los torneos acorde a sus propias demandas. En TSR no se han encontrado estudios que evalúen cómo afecta la superficie de juego sobre las demandas físicas, técnicas y tácticas de los jugadores masculinos o femeninos.

La gran cantidad de torneos internacionales y el aumento de los premios en metálico para los jugadores hacen que aumente el nivel competitivo de los mismos. Los jugadores usan diferentes estrategias y tácticas con la intención de maximizar sus oportunidades de ganar el partido. Las estrategias están basadas en el conocimiento de las propias fortalezas y debilidades, así como del oponente (O'Donoghue & Ingram, 2001). Este proceso es muy común en el deporte competitivo (Hughes & Bartlett, 2002; O'Donoghue, 2005) y ayuda a tomar decisiones tanto a los entrenadores como a los jugadores (O'Donoghue, 2007). Para ello, el análisis estadístico de las características del partido permite una comprensión más profunda de las razones para ganar o perder un partido (Filipcic, Caks, & Filipcic, 2011). En el TC diversos estudios han analizado las características de la competición desde un punto de vista del rendimiento (ganar o perder) (O'Donoghue & Ingram, 2001; Filipcic et al., 2011), pudiendo ayudar a los entrenadores en el diseño de las tareas a través del establecimiento de objetivos. En el TSR no se han encontrado estudios que describan las diferencias de ganar o perder un partido, así como aquellos aspectos del juego que determinan en mayor medida el rendimiento tanto en partidos masculinos como femeninos.

La estructura específica de este deporte, como son el volumen de puntos y el descanso entre puntos, le da un carácter intermitente similar al TC, con esfuerzos interválicos de moderada y alta intensidad, provocados por acciones repetitivas de corta duración pero de gran intensidad (Kovacs, 2007). Durante el tiempo de trabajo, la frecuencia cardiaca (FC) del jugador de TSR se sitúa en torno a 120-140 lat·min^{-1}, lo que supone una intensidad del 65-75% sobre la FC máxima con una estimación sobre el consumo máximo de oxígeno (VO_2max) del 50-68% considerándose como un deporte de moderada/alta intensidad (Barfield, Malone, & Coleman, 2009; Bernardi et al., 2010; Coutts, 1988; Croft et al., 2010; Roy et al., 2006; Sindall et al., 2013). Aunque se ha categorizado de esta forma, desde el punto de vista fisiológico sólo se tienen valores de

frecuencia cardiaca en competición. Los valores de otros indicadores de intensidad como la concentración de lactato en sangre (LA) o la Percepción Subjetiva del Esfuerzo (RPE) sólo han sido tomados durante sesiones de entrenamiento (Abel et al., 2008) obteniéndose valores aproximados de 2 $mmol \cdot L^{-1}$ y un valor de entre 12-13 la escala RPE. Ningún estudio en TSR se ha encontrado que evalúe la carga interna y externa del partido sobre el jugador con diferentes parámetros de cantidad e intensidad, que den una visión holística de las necesidades físicas y fisiológicas de la competición.

Profundizar en la investigación de esta especialidad deportiva, observar las diferencias entre género, superficie de juego, qué parámetros determinan a los ganadores frente a perdedores y qué demandas psicofisiológicas se obtienen en esta población, contribuirá a una mayor especialización del entrenamiento.

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OBJETIVOS GENERALES Y ESPECÍFICOS

OBJETIVOS GENERALES

- Analizar las demandas temporales, gestuales y psicofisiológicas del tenista en tenis en silla de ruedas de alto nivel.

OBJETIVOS ESPECÍFICOS

- Analizar la estructura temporal del tenis en silla de ruedas en tenistas de alto nivel.
- Analizar y comparar la estructura temporal del tenis en silla de ruedas en partidos masculinos y femeninos de nivel internacional.
- Analizar y comparar las demandas físicas y técnicas del tenis en silla de ruedas en jugadores y jugadoras sobre diferentes superficies de juego y, observar las posibles diferencias con el tenis convencional.
- Analizar los indicadores de rendimiento entre los ganadores y perdedores de tenis en silla de ruedas en los Juegos Paralimpicos de Londres 2012 tanto en jugadores masculinos como femeninas.
- Analizar la estructura gestual del tenis en silla de ruedas en tenistas de alto nivel y observar las posibles diferencias existentes en relación al género y a la superficie de juego.
- Analizar los requisitos psico-fisiológicos del jugador de tenis en silla de ruedas de alto nivel.

RESULTADOS Y DISCUSIÓN

El epígrafe Resultados y Discusión se presenta en el formato en el cual los artículos científicos han sido aceptados o enviados.

I

Match analysis in a wheelchair tennis tournament

Sánchez-Pay, A; Sanz-Rivas, D; Torres-Luque, G

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Cardiff Metropolitan University | Prifysgol Metropolitan Caerdydd

29th May 2015

To whom it may concern

The paper entitled "Match analysis in a wheelchair tennis tournament" written by Alejandro Sánchez-Pay, David Sanz-Rivas and Gema Torres-Luque has been accepted by the International Journal of Performance Analysis in Sport and will be published in Volume 15 Issue 2 which will be live on the journal's website run by Ingenta before 1st August 2015.

Yours

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Match analysis in a wheelchair tennis tournament

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Abstract

The aim of this study was to analyze the activity patterns of wheelchair tennis matches. 16 male singles tennis matches were played. Eight internationally ranked players were recorded and subsequently analyzed according to the following variables: total playing time, effective playing time, resting time (both in absolute values and as a percentage of total time). The average rally duration and the number of shots per rally were also recorded. The results showed a mean (SD) of match length of 61.70 (14.33) minutes, a effective playing time of 20.07 (3.67) %, a work:rest time ratio of 1:4.12 and an average duration of point of 6.93 (5.16) seconds. Most of the points end in 3 or less shots. No significant differences were found in rally duration and shots per rally with regards to non-breakpoint opportunities and breakpoint opportunities (p>0.05). Knowledge of the activity patterns within competition helps with specific training for the sport.

Keyword: adapted tennis, temporal structure, competition.

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Match analysis in a wheelchair tennis tournament

Abstract

The aim of this study was to analyze the activity patterns of wheelchair tennis matches. 16 male singles tennis matches were played. Eight internationally ranked players were recorded and subsequently analyzed according to the following variables: total playing time, effective playing time, resting time (both in absolute values and as a percentage of total time). The average rally duration and the number of shots per rally were also recorded. The results showed a mean (SD) of match length of 61.70 (14.33) minutes, a effective playing time of 20.07 (3.67) %, a work:rest time ratio of 1:4.12 and an average duration of point of 6.93 (5.16) seconds. Most of the points end in 3 or less shots. No significant differences were found in rally duration and shots per rally with regards to non-breakpoint opportunities and breakpoint opportunities (p>0.05). Knowledge of the activity patterns within competition helps with specific training for the sport.

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1. Introduction

Wheelchair tennis (WT) has been one of the most adapted sports and has developed significantly in recent years. Since the Paralympic games of Barcelona in 1992, it has grown professionally on court and institutionally off court, having a presence in over 41 countries with approximately 160 international tournaments within the NEC circuit (Bullock and Sanz, 2010). Wheelchair tennis matches are always played as best of 3 sets and the main difference regarding regulations in comparison to conventional tennis (CT) is that the ball can bounces twice before one must return it (ITF, 2012). Aspects such as rest time between points (20 seconds) and changes of ends (90 seconds) are the same as CT (ITF, 2012). Although rest periods are equal in both CT and WT, there is little information concerning activity patterns in WT, existing information is dissimilar between different studies.

However, the total time (TT) of a singles WT match is between 50 and 80 minutes (Croft et al., 2010; Filipčič and Filipčič, 2009; Roy et al., 2006; Sánchez-Pay et al., 2013; Sanz et al., 2009; Sindall et al., 2013) lasting less than the 90 minutes roughly registered in CT (Fernandez-Fernandez et al., 2009; Kovacs, 2007; Torres-Luque et al., 2014). As is the case with CT matches, the duration in wheelchair tennis will be determined largely by the playing level of participants (Filipčič and Filipčič, 2006, 2009), injure type (Sindall et al., 2013) or the playing surface amongst other variables (Sánchez-Pay et al., 2013). Moreover, the specific studies in WT show different values between types of match analyzed (official, played in a competition; or unofficial, simulates matches).

The intermittent nature of WT at regular permitted rest times, means that the effective playing time (EPT) is around 15-20% of the total playing time (TT), this is equivalent to a ratio of working time / resting time around to 1:4 (Filipčič and Filipčič, 2009; Roy et al., 2006). There

are few studies regarding to rally duration (RD), although it typically lasts between 4 and 10 seconds (Bullock and Pluim, 2003; Filipčič and Filipčič, 2009). During this time, the average numbers of shots per point are about four (Bullock and Pluim, 2003). This specific study was carried out in during the 2002 Paralympics games played on hard court. Although the results are from a decade ago, there are indications that WT is sport that is evolving year on year (Sanz et al., 2009).

Knowledge of the activity patterns of competition helps to improve training methods and provides information about the total amount of work, rest periods, series or repetitions of training exercises amongst many other aspects (Kovacs, 2007). Thus, the coaches will have information about time to make the exercise, time to rest between exercises, number of repetitions of series per exercises, etc. Therefore, it is necessary to deepen the activity patterns of a thriving specialty such as wheelchair tennis in order to contribute and improve specific knowledge of this given sport, leading to an improvement of training systems. Therefore, the aim of this study was to determine the activity pattern of wheelchair tennis during high-level competition.

2. Methods

2.1. Participants and general procedure

16 matches were recorded and subsequently analyzed during the Spanish Wheelchair Tennis Master Cup. The eight best nationally ranked players played this tournament. Four of them were positioned within the top 100 of the ITF rankings, and the other 4 within the top 200. All players trained 2-3 days per week and played at least 8-10 national or international tournaments that year to date. All matches were played on an indoor hard surface, yielding the same conditions. All matches were played with a referee, subsequently using new balls and having timed rest periods (between points and between changes of ends) that were strictly preserved according to the International Wheelchair Tennis Rules (ITF, 2012). In addition, all matches were completed in two sets.

The sample data of each variable was obtained from a total of 1678 points throughout 265 games and 16 matches. Total playing time was 65130 seconds (more than 16 hours).

2.2. Materials

Each match was filmed using a Panasonic HC- Panasonic HC-V700 (Panasonic-Japan) super wide angle. The camera was located in a corner of the court, outside of the fence, so that it could record the entire tennis court. The camera did not interfere with the game and could not be hit by a tennis ball. The videotapes were later replayed on a monitor for computerized viewing of the activity patterns. Reproduction was carried out using VCL Media Player software; furthermore, the timing factors were measured with a digital stopwatch (Casio, Tokyo, Japan) in relation to other studies with similar aims (Abian-Vicen et al., 2013; Abián et al., 2014; Kovacs, 2004).

Data were collected through systematic observation. Two experienced research and coach certified by Royal Spanish Tennis Federation were trained for observations. The observation process was developed in three phases. Firstly, the training process for each observer was done. Secondly, both of observers registered the same set on two occasions, separated by a four-week period for the purpose to calculate an intra-rater reliability. For this, Cohen's Kappa was used and 0.96 and 0.95 was obtained to each observer. Secondly, each observer analyzed two matches to calculate an inter-rater reliability. Cohen's Kappa was used and values obtained (table 1) were considered as very good (<0.80) (Landis and Koch, 1977).

Table 1. Intra and inter rater reliability for coding the actions.

	Intra-rater coefficient		Inter-rater coefficient
	Obs. 1	Obs. 2	Rate
Score in set	1	1	1
Score in games	1	1	1
Score in points	1	1	1
Type of point	1	0.96	1
Rally duration	0.85	0.84	0.81
Shots per rally	0.94	0.91	0.98
Total	**0.96**	**0.95**	**0.95**

Obs. = Observer

2.3. Variables

Each point was recorded in the database using the following process for all matches: a) Score (in sets, games and points) at start of point; b) Type of point (break point opportunity or non break point opportunity); c) Rally duration; and d) Shots per rally.

The description of the variables according to previous studies shown below (Kovacs, 2004; Mendez-Villanueva et al., 2007; O'Donoghue and Ingram, 2001; Torres-Luque et al., 2011):

- Rally Duration (RD) from the start of each serve until the end of the point, as the rules dictate (ITF, 2012).
- Total playing Time (TT): from the beginning of the match when one player is about to serve, until the last shot and the match ends.
- Shots per Rally (SR): determines the number of valid strokes made by the two players during a point.
- Points per Game (PG): total number of points played during a given game.
- Points per Set (PS): total number of points recorded in a set.
- Points per Match (PM): total number of points recorded during a match.

From the analyzed variables, other variables were derived including:

- Effective Playing Time (EPT): summation of the duration of each point during a given match.
- Total Rest Time (TRT) the summation of the resting time from the end of a point, until the player is ready again to restart play.
- Resting Time between Points (RTP)
- Working Time / Rest Time (W: R): a determination of the playing to rest time within a given match, stated as a ratio.
- Shots per Game (SG): summation of the total number of shots per game.
- Shots per Set (SS): summation of the total number of shots per set.
- Shots per Match (SM): summation of the total number of shots recorded per match.
- Shots per unit of time (S: T): ratio between the number of shots per unit of time (seconds).

Furthermore, points were categorized into break point opportunity (BO) or non break point opportunity (NBO).

2.4. Statistical Analysis

The data was obtained through the visual analyse of matches. This data was entered into spreadsheets (Microsoft excel, Spain) for processing purposes. From the spreadsheets, data was exported to IBM SPSS version 19.0 (IBM Corp., Armonk, NY, USA) for analysis. From the data the mean, standard deviation and range were calculated. The RD and SR variables were measured to know normality and homogeneity of variances. For this propose, Kolmogorov-Smirnov and Levene test were used. The results showed Kolmogorov-Smirnov $p<0.05$ and Leneve test $p< 0.05$, so Wilcoxon test (non-parametric) was used to compare RD and SR with the type of point (non breakpoint opportunity or breakpoint opportunity). Significance level was set at $p<0.05$.

3. Results

Table 2 shows the variables that depict the characteristics of the matches (TT, EPT, TRT, RT, RD, and W: R).

Table 2. Mean Standard Deviation (SD) and range for match analysis

	Mean	SD	Range
TT (minutes)	61.70	14.33	40.31 – 84.78
EPT (minutes)	12.37	3.44	7.30 – 18.40
TRT (minutes)	49.34	12.09	32.50 – 71.95
RT (between points)	28.27	25.88	6.00 – 221.00
EPT (%)	20.07	3.67	15.00 – 28.52
TRT (%)	79.93	3.67	71.48 – 85.00
RD (seconds)	6.93	5.16	1.00 – 43.00
W : R	1 : 4.12	-	1 : 2.51 – 1 : 5.67

TT: Total playing Time. EPT: Effective Playing Time. TRT: Total Resting Time. RTP: Resting Time between Points. RD: Rally Duration. W:R: Working Time / Resting Time.

Figure 1 show the duration of rallies during the series of matches. Most of the rallies (about 49%) lasted between 1 and 5 s and 82.87 % finished between 1 and 10 s.

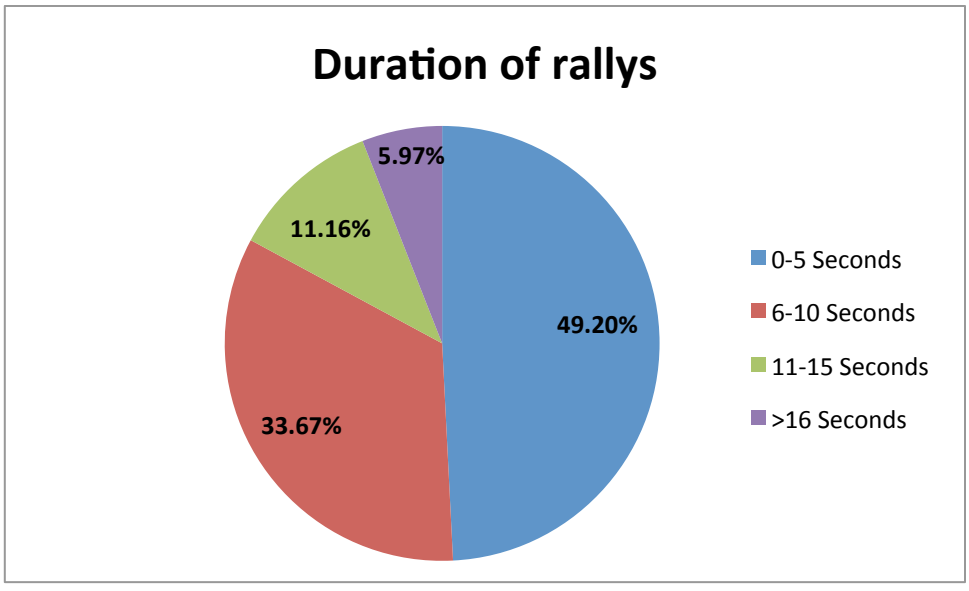

Figure 1. Distribution of rallies duration

Table 3 shows the variables related to the number of points and shots during the matches.

Table 3. Mean Standard Deviation (SD) and range for match analysis

	Mean	SD	Range
Points per match	104.88	21.50	71.00-135.00
Points per set	52.44	12.75	34.00-80.00
Points per game	6.33	2.30	4-14
Shots per match	357.50	87.32	219.00-504.00
Shots per set	178.75	57.06	85.00-305.00
Shots per game	21.44	10.32	6-47
Shots per rally	3.37	2.26	1.00-20.00
Shots / Second	2.05		

Figure 2 displays the number of strokes performed per player during the analyzed matches. Most of the rallies (about 64%) finished between 1 and 3 shots and 86.71 % last between 1 and 5.

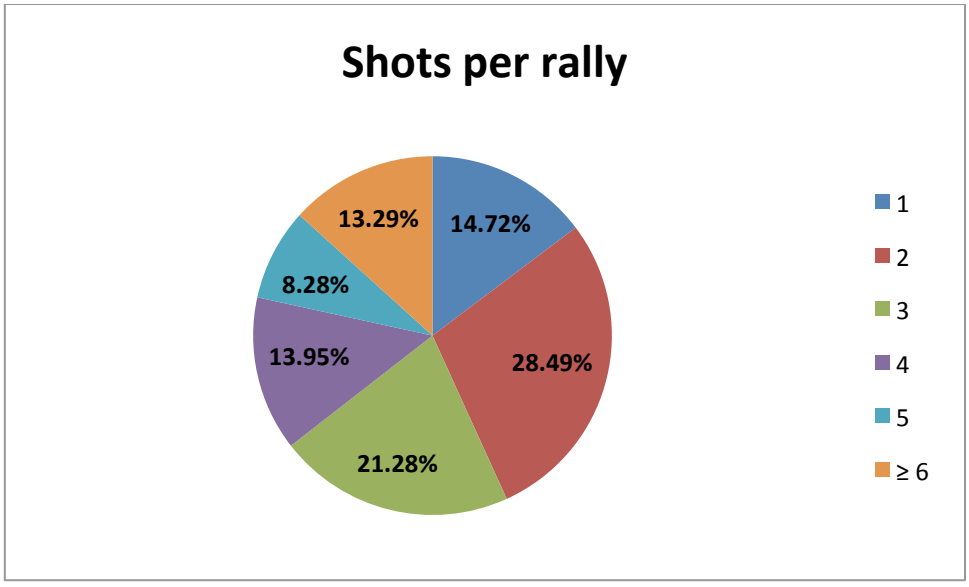

Figure 2. Distribution of number of shots per rally along a match

There is not a significant difference in rally duration between non-breakpoint opportunities (n=1206) and breakpoint opportunities (n=472) (Z=-1.378, p=0.168, fig. 3). Similarly, there is no significant difference in shots per point between both situations (Z-0.829, p=0.407, fig. 3).

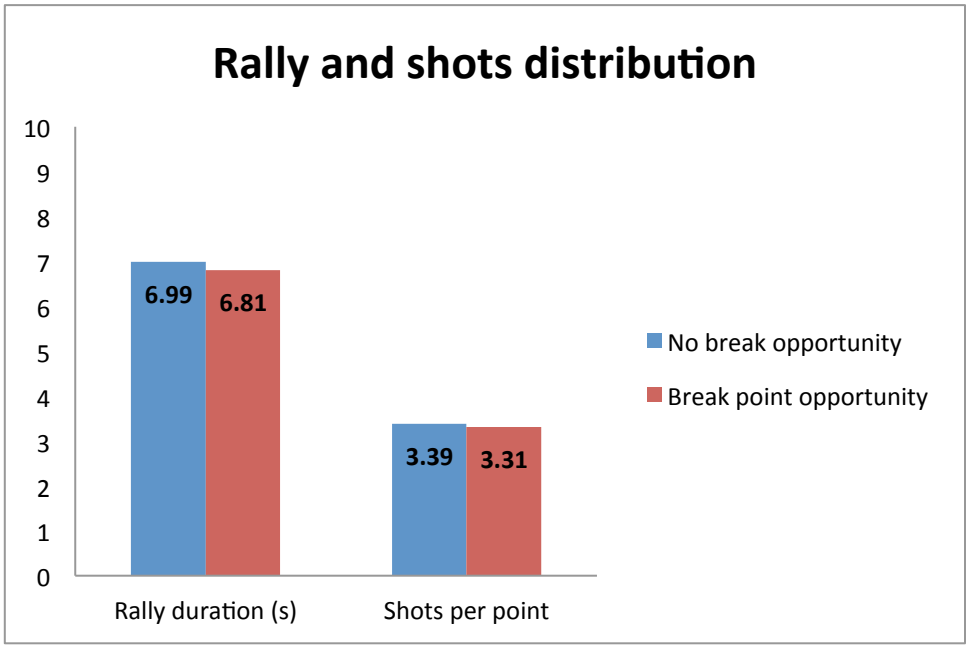

Figure 3. Rally duration and shots per rally in relation of type of points

Figure 4 shows the distribution of the number of shots per point in relation to the type of point. In this sense, there is no significant difference between the two situations (Z=-0.720, p=0.472). Both situations show a similar pattern regarding the distribution of the number of shots per rally.

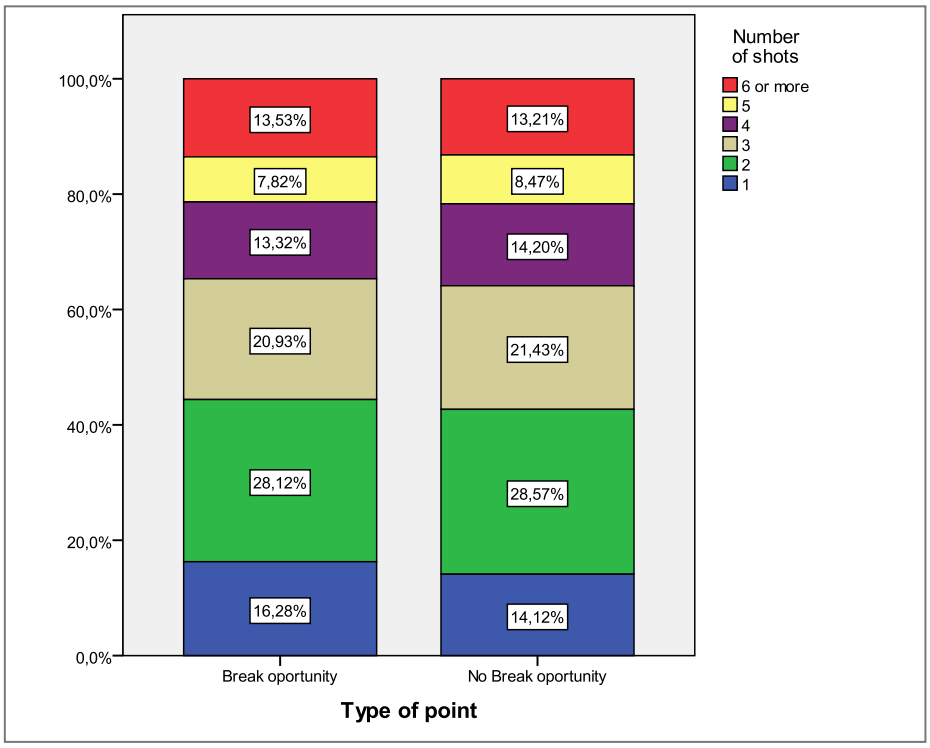

Figure 4. Distribution of the number of shots per point in relation to the type of point.

4. Discussion and conclusion

Knowledge of the activity patterns of competition helps to improve training methods and provides information about the total amount of work, rest periods, series or repetitions needed with training amongst many other things. To our knowledge, this is the first study that aims to have an approach to the playing characteristics of wheelchair tennis in high-level competition.

4.1 Temporal structure

Data from the present study shows a 61.70 ± 14.33 of total match time (TT) minutes (Table 2). These values are slightly lower than those recorded by Croft et al. (2010) and Sanchez-Pay et al. (2013) which obtained values close to 70 minutes. The differences are close to 10 minutes, this may be due to differences with the selected sample. In the study by Sanchez-Pay et al. (2013) the sample studied are the top 8 players in the ITF world rankings. Perhaps it could be argued that for the higher level players, the TT is higher due to the data published in the study of Filipcic and Filipcic (2009) where 10 players without ITF ranking were close to 55 minutes.

The ratio of effective playing time (EPT) and total resting time (TRT) is mainly determined by the rules of tennis (ITF, 2012). In this study, the EPT was 12.37 ± 3.44 (Table 2), representing 20% of the TT. This data is higher than the study carried out by Roy et al. (2006) and similar to Filipcic and Filipcic (2009), both unofficial match. There is no data on EPT high-level players, so if compared with conventional tennis studies, similar values would be obtained (Mendez-Villanueva et al., 2007). The percentage of EPT and TRT shows a W: D ratio of 1: 4.12 similar to that recorded in conventional tennis, which has a ratio ranging between 1: 3 and 1: 5 (Kovacs, 2007). This reaffirms the intermittent nature of this discipline, where there are higher values for TRT in comparison with EPT allowing the players preparation time for the next point. This information should be used when developing training and testing programmers for tennis players.

Regarding the rally duration (RD), the data from this study shows a mean of 6.93 ± 5.16 seconds per point (Table 2). The only other data found focusing on high-level international players was that produced by Bullock and Pluim (2003), it shows a mean time of 9.65 seconds. This finding, though different, may be due to the fact that only three matches were analyzed on the hard surface. The study was carried out in 2002. There are indications that the wheelchair tennis (WT) is evolving to become increasingly faster (Sanz et al., 2009). If this data is compared with that of lower level players, the RD is higher at 4.16 ± 0.60 seconds in recreational level (Filipcic and Filipcic, 2009), indicating the need to not only describe what happens, but negotiate in future, the difference in surfaces. Given the limited research, it is notable that the data found in this study in relation to the duration of the point, is similar to the data shown by male players at the U.S. Open or Australia Open, with values close to 7 seconds (Brown and O'Donoghue, 2008). This could be due to the possibility that the WT, and players hit the ball on the second bounce, allowing for more continuity within the game, but this is an aspect that has not been evaluated within this study.

Although points are observed with duration of 43 seconds (Table 2), almost 50% of them end within 6 seconds, and 82.87% by 11 seconds (Figure 1). Just found the study of Filipcic and Filipcic (2009) where the distribution of RD in a wheelchair tennis match in recreational level is evaluated, and a tendency to a lower RD are observed. Regardless, these data provide an

important reference for the work of the player on court, taking values of working time and rest time in the competition.

4.2 Points and shots

The data from this study showed a mean of 6.33 points per game, identical data to that found in conventional tennis in both the US Open and Australian Open (Cross and Pollard, 2009). This data suggests two things to be considered: firstly, the scoring system used in two modalities does not lead to a difference in the structure of the game, so that part of the number of series may be similar to conventional tennis. Secondly the deuce scenario (40-40) occurs much more frequently for wheelchair tennis players during the match, this aspect should be taken into account when psychological work is undergone regarding dealing with break point opportunities.

Although it has been concluded that points lasting 20 shots have a shots per rally (SR) mean of 3.37, slightly higher values to that found by Bullock and Pluim (2003) that came in at 3.00 SR in the Paralympics games. The game play makes about 87% of the points and will end up with 5 hits or less (Figure 2). The results show that in the serve/return situation is more than 43% of the point. The data provides two things to reflect on: firstly, that serving/returning scenarios are vital in wheelchair tennis, and secondly, that the returning player makes more than 42% of all the shots in him first two shots (return and fourth shots). Although unevaluated is the quality of each shot, it could be said that it is important to carry out tasks in short duration with emphasis on effectiveness in a training session on court.

An interesting variable regarding applicability to training is the numbers of shots per second; this is because it gives useful information relating to the speed of the game (timing). This is a novel finding, because to our knowledge literature on this variable is very scarce. As shown in this study a shot occurs every 2.05 seconds (Table 3). Only one other study has been found in wheelchair tennis at the professional level based on hard courts and this study determined that a shot occurs every 2.06 s (Bullock and Pluim, 2003), although this is our an estimate and not a factual statistic. Compared to conventional tennis, observed is that wheelchair tennis in slower. Studies in slow motion show approximate values of one shot every 1.2 seconds (O'Donoghue and Ingram, 2001). During the time interval between each shot, a player has to relocate the chair via pivot (rotate with the chair) to a position on the court as fast as possible and prepare for the next shot (Sanz, 2003).

4.3 Break and non break point opportunity

The data from this study doesn't show statistical differences ($p>0.05$) between breakpoint opportunities (BO) and non-breakpoint opportunities (NBO) in relation to RD (figure 3). This indicates that the activity pattern does not change. However it may do so with different types of stroke or the performance of each of these strokes, as happens in conventional tennis (Klaassen and Magnus, 2001; Knight and O'Donoghue, 2012). These are aspects that have not been evaluated in this study. Similarly, the SR did not show significant differences ($p> 0.05$) when compared to situations BO or NBO (figure 3 and 4). This means that the wheelchair tennis player has the same playing rhythm (shots and rally duration) whatever type of point.

Our study had some limitations. An important limitation is the level of subjects, although they were elite national level, no they are the top 10 international ranking. Also, it is important to consider that the values obtained refer to a hard court it would be interesting to compare between surface and kid of injury.

The result of this study was to attempt to show the activity pattern characteristics of high-level men's wheelchair tennis matches played at competition level on hard courts. In conclusion, it has been observed that the duration of wheelchair tennis matches are around 61 minutes long. These have an effective playing time of 20%, so the ratio of working time/rest time is 1: 4. Similarly observed was an average of points lasting 7 seconds. Wheelchair tennis players hit an average of slightly more than 3 shots per point, which results in a hit of once every 2 seconds. Coaches and fitness trainers can use the information provided within this study to improve the specific training programs and tactics for players.

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II

Activity pattern in male and female wheelchair tennis tournament

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Kinesiology

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ORIGINAL ARTICLE

Activity patterns in male and female wheelchair tennis tournaments

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Abstract

The aim of this study was to compare the activity patterns between male and female wheelchair tennis (WT) matches. Sixteen single international WT matches (eight male and eight female) were analysed. Each match was recorded and analysed according to the following variables: total match time (min), total set time (min), effective playing time (%), total resting time (%), working time : resting time ratio (W:R), resting time between points (s), rally duration (s), points per set, shots per set, shots per rally, bounces per point, and frequency of shots (s). A Mann–Whitney U test was used to compare between the genders and a Wilcoxon test was used to compare variables with the type of point (non-break point opportunity or break point opportunity). Female matches showed higher values ($p<.05$) in rally duration, bounces per point, and frequency of shots than male matches. Both genders spent more time between points in a break situation than a non-break situation. The result shows that male and female players play in a different way, and these differences should be taken into consideration by the wheelchair tennis coach.

Key words: *adapted tennis, gender, match activity*.

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Introduction

Knowledge of the activity patterns of competition helps to improve training methods and provides information about the total amount of work, rest periods, series or repetitions of training exercises amongst many other aspects (Kovacs, 2007). Activity patterns have been extensively studied in racket sports such us badminton (Abian-Vicen, Castanedo, Abian, & Sampedro, 2013; Cabello-Manrique & Gonzalez-Badillo, 2003), squash (Girard, Chevalier, Habrard, Sciberras, Hot et al., 2007), paddle tennis (Carrasco, Romero, Sañudo, & De Hoyo, 2011), table tennis (Zagatto, Morel, & Gobatto, 2010) or tennis (Fernandez-Fernandez, Sanz-Rivas, & Mendez-Villanueva, 2009; Kovacs, 2004; O'Donoghue & Ingram, 2001). Adapted racket sports have also been studied, to a lesser extent. Wheelchair tennis (WT) is the adapted racket sport that has gained most ground in recent years (Bullock & Sanz, 2010). Activity patterns have been studied over the last 10 years showing the total time (TT) of a singles match to be between 50 and 80 minutes (Croft, Dybrus, Lenton, & Goosey-Tolfrey, 2010; Filipčič & Filipčič, 2009; Roy, Menear, Schmid, Hunter, & Malone, 2006; Sánchez-Pay, Torres-Luque, Fernández-García, & Sanz-Rivas, 2013; Sanz, Cid, Fernández, & Reina, 2009; Sindall, Lenton, Tolfrey, Cooper, Oyster et al., 2013), the effective playing time (EPT) to be around 15–20% of the total playing time (TT), which is equivalent to a ratio of around 1:4 of working time/resting time (Filipčič & Filipčič, 2009; Roy et al., 2006), and the rally duration (RD) to be between 6 and 10 seconds, with 3–4 shots per rally (SR) (Bullock & Pluim, 2003; Sánchez-Pay, Sanz-Rivas, Montiel, Zanco, & Torres-Luque, 2015; Sanchez-Pay, Sanz-Rivas, & Torres-Luque, 2015; Veltmeijer, Pluim, Thijssen, Hopman, & Eijsvogels, 2014). All these studies were on male players, so there are no results for female WT matches.

Differences in activity patterns according to gender have been studied in racket sports. Principally, conventional tennis (CT) has been studied the most and differences have been found between the genders (Brown & O'Donoghue, 2008; O'Donoghue & Ingram, 2001). Differences in activity patters show specific needs in the game, so the training system should be adapted to gender.

Thus, activity patterns have been studied in different adapted sports such as sitting volleyball (Häyrinen & Blomqvist, 2006), sledge ice hockey (Häyrinen, Juntunen, Blomqvist, Övermark, Molik et al., 2011), and wheelchair basketball (Croft et al., 2010), but no study has compared possible differences between the genders. There are

no previous measurements for adapted sports concerning activity patterns by gender, so we do not know how these values would be affected. Therefore, the aim of this study was to determine the activity pattern of wheelchair tennis during high-level competition and show the differences by gender.

Method

Participants

Sixteen international WT matches (eight male matches and eight female matches) were recorded and subsequently analysed during an international tournament included into the International Tennis Federation (ITF) wheelchair tennis tour. All matches were played on outdoor hard courts under ITF rules (ITF, 2012). The best international ranking players competed in this tournament, qualifying through a competition system in the Open Division. Male players had an ITF ranking of between 30 and 125, and female players an ITF ranking of between 20 and 90. The sample data of each variable was obtained from a total of 1926 points throughout 16 matches.

Procedure

Each match was filmed using a Panasonic HC-V700 (Panasonic-Japan) camera with super wide angle. A total of eight cameras were used because the first round of the male competition was played in eight courts at the same time. The cameras were located in a corner of the court, outside the fence, so that it could record the entire tennis court and did not interfere with the game. Each camera recorded 30 frames per second. The videotapes were later replayed on a monitor for computerized viewing of the activity patterns.

The analysis was carried out using Lince software (Gabin, Camerino, Anguera, & Castañer, 2012). This software enables one to code every action (e.g. shots per rally) and also shows the duration of the action (e.g. rally duration) in milliseconds. Furthermore the changes between changeovers were excluded from the resting time and total set time.

Data were collected through systematic observation. For this purpose, two tennis coaches experienced in research and certified by the Royal Spanish Tennis Federation were trained for observations. Intra-rater reliability was calculated through each

observer registering the same period of play (one set) on two occasions separated by a four-week period. Cohen's Kappa was used and 0.95 and 0.91 was obtained for each observer. After that, each observer analysed two matches to calculate an inter-rater reliability. Cohen's Kappa was used and values obtained were considered as very good (<0.80) (Landis & Koch, 1977).

Variables

Each point was analysed following the same procedure: a) gender of the match; b) set number; c) game number; d) score in a game; e) start of rally; f) finish of rally; g) total shots in rally; h) total bounce number; and i) point winner player. This process generated the following variables according to other wheelchair and conventional tennis studies (Kovacs, 2004; O'Donoghue & Ingram, 2001; Sanchez-Pay et al., 2015; Torres-Luque, Cabello-Manrique, Hernández-García, & Garatachea, 2011):

- Total match time (min): from the beginning of the first point, until the last point and the match ends.
- Total set time (min): from the beginning of the first point in a set, until the last point and the set ends.
- Effective playing time (%): summation of the duration of each point during a given match.
- Total resting time (%): summation of the resting time from the end of a point, until the next point begins.
- Working Time/Rest Time: a determination of the playing to rest time within a given match, stated as a ratio.
- Resting time between points (s): from the end of a point until the next point begins.
- Rally duration (s): from the start of each point until the end of the point, as the rules dictate (ITF, 2012).
- Points per set: total number of points recorded in a set.
- Shots per set: summation of the total number of shots per set.

- Shots per rally: determines the number of valid strokes made by the two players during a point.
- Bounces per point: determines the number of total bounces in a point.
- Frequency of shots (s): ratio between the number of shots per unit of time (seconds).

The point began when the player started to separate his/her hands' in a serve movement. Moreover, in a double fault situation the point finished when the ball bounced out or touched the net. Furthermore, points were categorized into non-break point opportunity (NBO) or break point opportunity (BO) and by gender (male or female).

Statistical analysis

The data were obtained through the visual analysis of matches. These data were entered into spreadsheets (Microsoft excel, Spain) for processing purposes. From the spreadsheets, data was exported to IBM SPSS version 19.0 (IBM Corp., Armonk, NY, USA) for analysis. From the data the mean, minimum, maximum, and standard deviation were calculated. All variables were measured to know normality of variances. For this proposes, the Levene test was used. The results showed $p<.05$, so non-parametric tests were used. A Mann–Whitney U test was used to compare between the genders, and a Wilcoxon test was used to compare variables with the type of point (non-break point opportunity or break point opportunity). Resting time between points, rally duration, shots per rally, bounces per point, and frequency of shots variables were normalized, with the aim of comparing NBO variables between the genders and BO variables between the genders. Thereafter, a Mann–Whitney U test was used.

Subsequently, shots per rally and rally duration were categorized. Six or more shots in a point were grouped as +5 shots, and rally duration was categorized by range: 0–5 seconds, 6–10 seconds, 11–15 seconds, and more than 15 seconds. Shots per rally and rally duration were expressed in percentage, so a Z-test was used to compare proportions between the genders. Significance level was set at $p<.05$.

Results

Table I shows match activity in male and female wheelchair tennis matches and statistical differences between both.

Table I. Mean (M), standard deviation (SD), and statistical differences in match activity between male and female matches

	Male	Female	Differences	
	M ± SD	M ± SD	P Value	Z value
Total match time	64.65 ± 13.36	77.62 ± 31.67	.833	-.211
Total set time	30.43 ± 8.04	34.50 ± 9.06	.165	-1.387
Effective playing time (%)	20.77 ± 3.42	22.32 ± 5.22	.373	-.892
Total resting time (%)	79.23 ± 3.42	77.68 ± 5.22	.373	-.892
W:R ratio	3.95 ± 0.86	3.72 ± 1.11	.373	-.892
Resting time between points	23.98 ± 9.69	25.91 ± 17.96	.065	-1.848
Rally duration	5.58 ± 3.65	6.82 ± 4.83	**.000**	-5.839
Points per set	53.53 ± 11.34	58.11 ± 14.83	.467	-.728
Shots per set	157.24 ± 31.07	180.50 ± 77.82	.766	-.297
Shots per rally	2.90 ± 1.71	3.10 ± 2.01	.095	-1.669
Bounces per point	2.46 ± 1.85	2.97 ± 2.53	**.000**	-3.518
Frequency of shots	1.90 ± 0.38	2.15 ± 0.41	**.000**	-12.930

Female matches showed higher values in almost all variables. Specifically, female players have longer rally duration ($p<.001$) than male players. In contrast, during male points the ball bounces less times than during female points (2.46 ± 1.85 vs 2.97 ± 2.53, respectively). Moreover, male players hit the ball every 1.90 ± 0.38 seconds, statistical less than female players (2.15 ± 0.41).

Table II shows statistical differences in match activity between non-break point opportunity (NBO) and break point opportunity (BO) situations in male and female matches. Moreover, the table shows statistical differences in NBO and BO between the genders.

Table II. Statistical differences in match activity between type of point and gender.

	Male			Female			Dif. Gender	
	NBO	BO	P value	NBO	BO	P value	NBO	BO
Resting time between points	22.72	28.76	**.000**	23.88	33.01	**.000**	.067	.429
Rally duration	5.51	5.75	.264	6.79	6.86	.236	.808	.723
Shots per rally	2.87	2.96	.324	3.08	3.17	.116	**.000**	**.008**
Bounces per point	2.47	2.44	.718	2.95	3.04	.100	**.000**	.268
Frequency of shots	1.89	1.91	.399	2.16	2.13	.225	.236	.297

Male and female players play a break point opportunity and a non-break point opportunity in the same way. There are significant differences only in resting time ($p<.001$), both spending more time in BO. Between the genders, the shots per rally variable shows significant differences in NBO ($p<.001$) and BO ($p = 0.008$) and female points have more bounces in NBO than male points ($p<.001$).

Figure 1 shows the distribution of shots per rally in male and female matches. No significant differences were found between the genders with each group of shots. Both male and female players finish most of the points in the second shot. The first two shots (serve and return) represent 51.9% in male and 49.2% in female players.

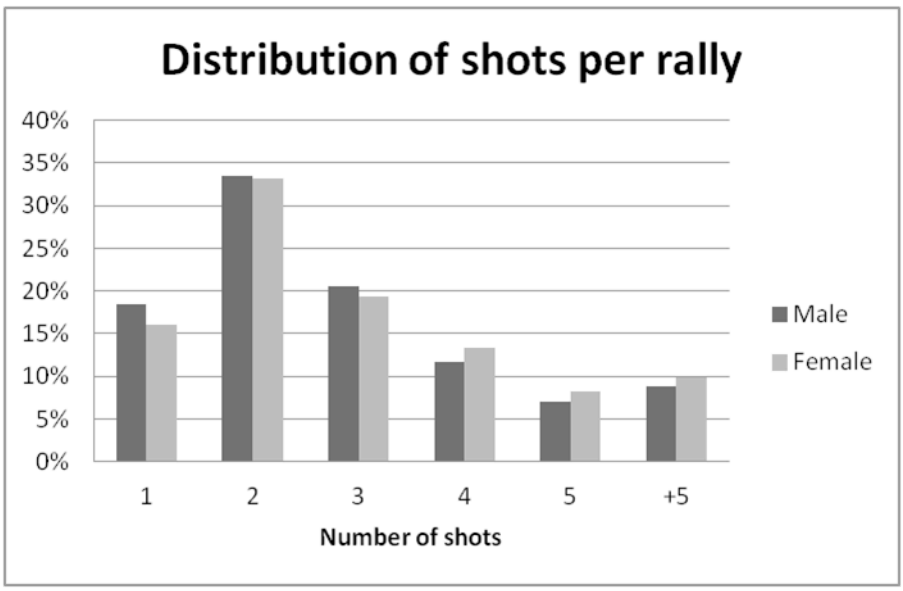
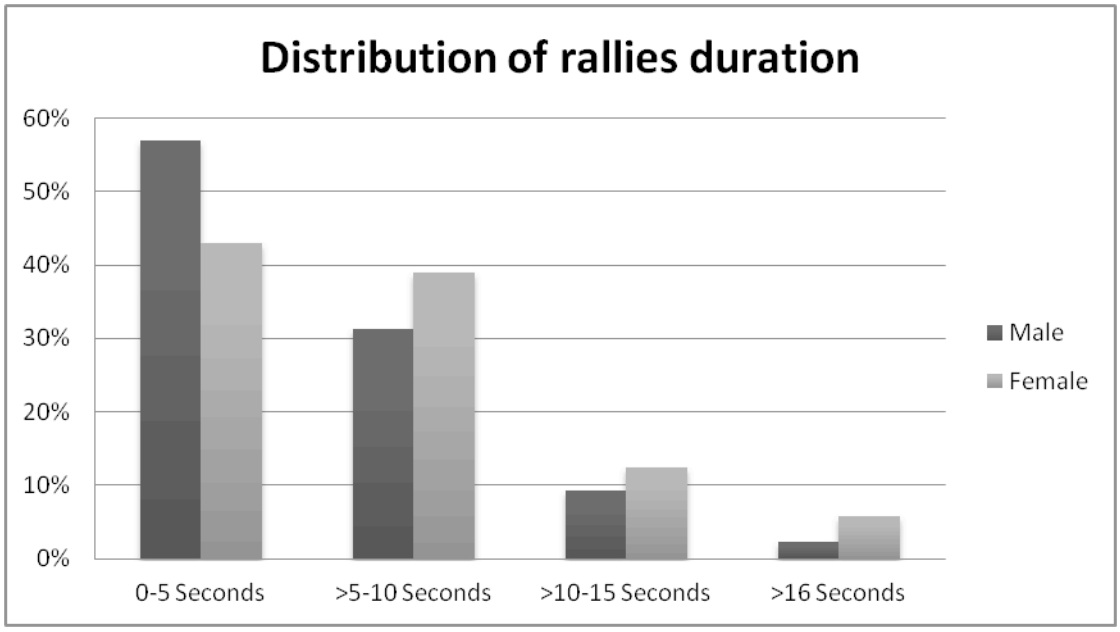


Figure 2 shows the distribution of rally duration in male and female matches. Significant differences were found ($p<.05$) between the genders in all ranges of time. The greatest differences between groups were in the 0–5 seconds range (57.04% in male and 42.90 in female matches). In male matches, 31.35% of the total points finished between more than >6 and 10 seconds; in female matches this was 38.89%.



Discussion

The aim of this study was to approach to the playing characteristics of wheelchair tennis in high-level competitions and show differences between the genders (male and female matches). No studies have been found on female wheelchair tennis matches, so in the discussion the authors will compare the results with female conventional tennis matches.

Data show that total match time (TT) in male matches (64.65 ± 13.36) is lower than in female matches (77.62 ± 31.67), although the differences are not significant (Table I). Male matches have a similar total match time to other studies on the top ten ITF ranking on hard court (Sánchez-Pay et al., 2013). The differences between the genders in the total match time variable could be due to more matches being played to three sets shown in a higher standard deviation in female matches (Table I).

The percentage of effective playing time (EPT), percentage of total resting time (TRT), and W:R ratio have a direct relation among them, so have the same statistical differences (p=.373). Specifically, female players have higher values than male players in all of them. The percentage of EPT and TRT shows a W:R ratio of 1:3.95 in male matches and 1:3.72 in female matches, so female WT matches could be considered more continuous than male WT matches, although significant differences did not found. From a general point of view, EPT is between 20-22% (Table 1) and this range is similar than male and female CT matches (Fernandez-Fernandez, Mendez-Villanueva, Fernandez-Garcia, & Terrados, 2007; Fernandez-Fernandez, Sanz-Rivas, Sanchez-Muñoz, Pluim, Tiemessen et al., 2009; Mendez-Villanueva, Fernandez-Fernandez, Bishop, Fernandez-Garcia, & Terrados, 2007), so seems that WT has a similar activity pattern than CT.

Rally duration (RD) is statistically higher ($p<.001$) in female matches than male matches (6.82 ± 4.83 seconds and 5.58 ± 3.65 seconds respectively). The higher values in RD could explain the need of female players to use more time between points for rest and preparing for the next point. The differences in rally duration between male and female matches (Table I) follow the line of conventional tennis, where rallies on hard courts are longer in female than male matches (Brown & O'Donoghue, 2008; O'Donoghue & Ingram, 2001). The short rally duration in male matches could be a consequence of fewer shots per rally (SR) in male (2.90 ± 1.71) than female matches (3.10 ± 2.01), although not significant differences were found. From a general point of view, the number of shots per rally is similar to other studies in male high level WT matches (Bullock & Pluim, 2003; Sanchez-Pay et al., 2015; Veltmeijer et al., 2014) and higher than recreational level matches (Filipčič & Filipčič, 2009), so SR could be influenced by the level of the players. Male and female players have a similar distribution of shots per rally (Figure 1), but RD shows a different distribution between the genders (Figure 2). This reaffirms the idea that female matches have longer rallies than male matches.

The main difference between WT and CT is that the ball can bounce twice before one must return it (ITF, 2012). In this study the ball bounced about 2.5 times in a point in male matches and 3 times in female matches. It is important to note that the service shot involves hitting without a bounce, so the first shot after the first bounce is the return shot. Therefore, in the shots per rally variable we have to subtract one shot (1.9 in

male and 2.1 in female matches). Thus, male players used a mean of 1.29 bounces per shot and female players 1.41. This suggests that female players use the second bounce rule more than male players. No studies have been found on the reason for using the first or second bounce. Its use could be due to different reasons: on one hand, women hit the ball with less power than men, and the ball needs to bounce twice to arrive in the baseline region where players spend most of their time (Filipčič & Filipčič, 2009); on the other hand, the second bounce is usually used to play a defensive shot, further away from the baseline (Sanz, 2003). These could be some of the reasons for the differences and could help in understanding the differences between the genders in the frequency of shots variable ($p<.001$). In this way, male players hit the ball every 1.90 second and female player every 2.15 seconds. This shows that men's matches have more speed in the game (timing) than women's matches. Previous studies showed the rate as one shot every 2.05 seconds in a male national wheelchair tennis competition (Sanchez-Pay et al., 2015). No studies have been found in female WT matches about this variable, although the differences between the genders in the speed of the game follow the line of conventional tennis where women's matches are slower than men's matches (O'Donoghue & Ingram, 2001).

Previous studies analysed the activity pattern in non-break point opportunities (NBO) and break point opportunities (BO) (Sanchez-Pay et al., 2015) with the aim of understanding how these situations affect to the way players play. No significant differences were found in rally duration and shots per rally in a male national competition. No other variables were analysed and nor is there any information on female matches. In this study male and female matches only showed significant differences in resting time between points (Table II). Resting time between points was higher in BO than NBO in male (28.76 and 22.72 seconds) and female (33.01 and 23.88 seconds). This could indicate that players spent more time resting and preparing for the next point as a consequence of the greater importance for the score. In NBO situations, female players played more shots and used more bounces per point than male players, although only shots per rally shows differences between the genders in the BO situation. This indicates that male and female players play points in a different way, and this should be taken into consideration by wheelchair tennis coaches.

Our study had some limitations. Although the matches analysed were part of an international competition, they are not the top ten international ranking. Also, it is

important to consider that the values obtained refer to a hard court; it would be interesting to compare between surfaces and level of injury.

Conclusion

The results of this study was to attempt to show the activity pattern in male and female wheelchair tennis matches and show the differences between the genders in high-level wheelchair tennis matches on hard courts. In conclusion, it has been observed that female points are longer, and female players hit the ball more times per point than male players. In contrast, male points are faster and male players used less bounces to finish the point than females. Both spent more time between points in break point opportunities than non-break point opportunities. Moreover, male and female players play NBO and BO in a different way in relation to shots per rally. These values can be used by coaches and fitness trainers to improve the specific training programs and tactics for each gender.

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III

Differences in set statistics between wheelchair tennis vs conventional tennis in different types of surface and gender

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Title

Differences in set statistics between wheelchair and conventional tennis on different types of surfaces and by gender.

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Abstract: The aim of the present study was to analyse the differences in match statistics between conventional tennis (CT) and wheelchair tennis (WT) on different surfaces by gender. Data from 220 sets (127 sets of CT and 93 of WT) from three of the 2014 Grand Slams (Australian Open (AO), Roland Garros (RG), and US Open (UO)) were analysed. The variables related to match (total match time, points played, games per set, and points per game), serve (aces, double faults, ratio of aces/double faults, percentage of first and second serves, points played and won on first and second serves), and return (break point opportunities and won, receiving points played and won, and total points won) were studied in relation to the modality of the match (CT or WT) and type of surface (AO, RG, or UO). Data were collected from the official website of each tournament. A univariate (Mann Whitney U) analysis of data was done to analyse the differences between modalities and types of surface. The results showed that CT players had better serve performances than WT players. However, WT players had better performances in the return than CT players. The values between CT

and WT for female players were more similar than male players. Regarding court surface, players of CT had more differences in game statistics than WT for both genders. These values could be used as a reference for peak performance players' practices and competitions as well as to aid in the understanding of the differences between modalities.

Keywords: match analysis, performance, and racket sports.

INTRODUCTION

Conventional tennis (CT) is one of the most practiced sports worldwide, and the first of those considered to be racket sports [1]. Tennis has been adapted for people with disabilities with the main objective of facilitating its practice to all persons regardless of their abilities. Wheelchair tennis (WT) has developed significantly in recent years. The rules are similar for both, although the primary difference between WT and CT is that the ball can bounce twice before a player hits it in WT [2]. Besides the differences in rules, the other major difference is that players are sitting in a wheelchair, which affects the sport's demands and the player's needs. For CT and WT, there are two aspects of the game that affect it: the type of surface and the ball. In relation to the court pace rating, tennis regulation differences the following types of surface: 1 (slow pace), 2 (medium-slow pace), 3 (medium pace), 4 (medium-fast pace), and 5 (fast pace). Regarding the types of balls, the International Tennis Federation (ITF) recognises three types from 1, fast, to 3, slow. These two aspects impact the speed of the game and, therefore, the length of rallies. These aspects mean that tennis can be played under different conditions, and this needs to be considered by strength and conditioning coaches and tennis coaches.

The analysis of the competition provides value information which allows us to define the technical-tactical demands of the game for the players [3]. The studies in this area provide information about the way the game is played on different surfaces [4,5] or allow us to understand the differences between players of different levels [6,7]. The available information has shown that CT players have a greater ability for displacement, a greater ability for recovery, a higher ball contact height, and they hit the ball harder than WT players [8-12]. Additionally, the court surface is related to the way players play the game and, therefore, match statistics [4,5,13]. There is less information about WT than CT (research studies,

training manuals, etc.). The lack of specific information does not allow tennis coaches to have objective information to adapt their practice to the needs of WT tennis players. More knowledge about athletes' performances can help improve the quality of play and will assist coaches in the development of this sport.

Therefore, the available data have allowed us to hypothesise that there may be differences in match statistics between modalities (CT and WT) and also between surfaces. The aim of this study was to analyse the game statistics of men's and women's conventional tennis and wheelchair tennis matches on different surfaces.

METHOD

Samples

The sample was 96 players (24 men from CT, 24 men from WT, 24 women from CT, and 24 women from WT). Data from 220 sets (127 sets in CT and 93 in WT) from the 2014 Australian Open, Roland Garros, and US Open were analysed (table 1). The Grand Slam of Wimbledon was not included in the sample, because WT players did not play in it. The sample represents 100% of all matches played by eight male and eight female WT players in the open division (the tournament began in quarter finals) and eight male and eight female CT players that played the last round (quarter finals, semi-finals, and finals) of the CT tournament. In these tournaments, the best internationally ranked players played to qualify through a competition system. The unit of analysis was the set to prevent differences in comparing CT matches (best of five sets) and WT matches (best of three sets).

Table 1. Number of sets analysed by tournament, modality, and sex.

	Australian Open		Roland Garros		US Open		Total
	CT	WT	CT	WT	CT	WT	
Men	28	15	27	16	26	16	128
Women	16	16	12	15	18	15	92
Total	44	31	39	31	44	31	**220**

CT: Conventional Tennis; WT: Wheelchair Tennis

Variables

The variables studied in the WT and CT competition were: a) variables related to match: total match time, total points played, games per set, and points per game; b) variables related to

serve points: aces, double faults, ratio of aces/double faults, percentage of first serves, points won on serve, points played on first serve, percentage of points won on first serve, points won on second serve, points played on second serve, and percentage of points won on second serve; and c) variables related to return points: break point opportunities, break points won, percentage of break points won, receiving points won, receiving points played, percentage of receiving points won, and total points won.

Procedure

The sample was divided into sub-groups for its analysis: a) tournament: Australian Open (AO), Roland Garros (RG), or US Open (UO). Each tournament was played on different surfaces and with different balls. The AO was played on a hard court (category 3) with type 2 balls. Roland Garros was played on a clay court (category 1) with type 1 balls. The UO was played on a hard court (category 4) with type 2 balls: and b) modality: conventional tennis (CT) or wheelchair tennis (WT).

Statistical analysis

Data were collected from the official website of each tournament. A specifically designed spreadsheet (Microsoft Excel) was used to collect all the statistics, which were then exported to the IBM SPSS version 20.0 (IBM Corp., Armonk, NY, USA) statistical program for analysis. Firstly, a descriptive analysis of the data (means (M) and standard deviation (SD)) was done. Secondly, the Shapiro-Wilk test (normality) and the Levene test (homogeneity) were used. Thirdly, a univariate (Mann Whitney U) test (non-parametric) was carried out with the aim of analysing the differences between modalities (WT and CT) and tournaments (AO, RG, and UO) in set statistics, because the assumptions of normality and homogeneity of variances were not satisfied. Unfinished matches were not included in the database. Significance was set at $p<0.05$.

RESULTS

The means (M) and standard deviation (SD) of set statistics in conventional tennis (CT) and wheelchair tennis (WT) in the analysed men's Grand Slam tournaments are demonstrated in Table 2.

Table 2. Descriptive statistics for men's CT and WT sets.

	Australian Open				Roland Garros				US Open			
	CT		WT		CT		WT		CT		WT	
Variables	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Variables related to match												
Total set time (minutes)	47.75	14.22	33.87	13.44	44.26	13.15	39.75	12.09	41.35	9.43	42.59	13.44
Total points played	63.86	14.91	57.40	23.16	62.81	15.99	66.38	17.19	54.92	12.97	69.71	20.71
Games per set	10.14	2.24	8.80	2.44	10.22	1.83	8.94	2.05	9.00	1.75	9.76	2.40
Points per game	6.32	.82	6.34	.96	6.09	.70	7.42	.99	6.10	.87	7.12	0.90
Variables related to serve points												
Ace	2.57	2.26	1.00	1.02	2.48	2.17	1.03	1.06	1.63	1.99	1.18	1.19
Double faults	.75	.96	2.23	2.47	1.04	1.24	1.59	1.24	.69	.73	1.97	1.73
R. Aces/Double faults	2.15	2.17	.62	.75	1.89	1.76	.73	.68	1.43	1.65	.83	1.10
Points played on first serve	20.13	6.23	19.43	8.22	18.19	5.70	22.38	7.99	17.79	5.53	22.26	8.93
Total points played on serve	32.09	9.05	29.03	12.03	31.41	8.69	33.50	10.36	27.46	7.20	34.85	11.23
First serve (%)	62.96	10.20	68.11	14.74	57.96	8.81	66.82	10.52	64.73	9.91	63.26	10.40
Points won on first serve	14.64	5.00	11.50	5.38	13.35	4.59	12.72	4.81	12.60	4.70	12.97	4.95
Points won on first serve (%)	73.04	12.42	58.38	17.80	73.15	12.33	57.13	12.55	70.43	15.24	59.65	14.90
Points won on second serve	6.30	2.92	3.83	2.51	6.70	2.84	4.56	2.54	4.69	2.48	5.74	2.68
Points played on second serve	11.80	4.89	9.60	6.01	13.22	4.51	10.81	4.80	9.67	3.34	12.59	5.01
Points won on second serve (%)	53.01	15.46	44.22	26.38	51.22	17.43	42.75	14.91	47.68	20.71	45.82	13.24
Variables related to return points												
Break points won	.75	.79	1.97	1.35	1.00	.85	1.97	1.15	1.06	1.02	1.94	1.41
Break point opportunities	2.02	2.17	3.67	2.43	2.50	1.72	4.47	2.51	2.37	1.98	4.88	3.85
Break points won (%)	32.20	36.58	47.51	30.49	39.48	35.68	48.77	28.36	40.04	40.00	38.50	27.21
Receiving points won	10.80	4.17	13.70	7.14	11.35	4.67	15.91	5.91	10.17	4.00	16.15	7.08
Receiving points played	31.93	9.00	29.03	12.03	31.41	8.69	33.19	10.41	27.46	7.20	34.85	11.23
Receiving points won (%)	33.89	9.13	46.23	16.62	35.74	10.36	47.63	10.96	37.48	14.35	45.53	11.18
Total points won	31.93	8.42	28.70	13.15	31.41	8.86	33.19	9.84	27.46	8.24	34.85	11.23

Legend: CT: Conventional Tennis; WT: Wheelchair Tennis; R.: Ratio.

The statistical differences in men's sets between modalities (CT and WT) and tournaments (AO, RG, and UO) are shown in Table 3. Data express the p-value and the tournament where significant differences were found.

Table 3. Statistical differences in game statistics for men's sets between modalities and tournaments.

	Modalities (CT vs. WT)			Tournament	
	AO	RG	UO	CT	WT
Variables related to match					
Total set time	**.000**	.238	.958	AO>UO*	AO<UO**
Total points played	**.030**	.381	**.002**	AO>UO** RG>UO*	AO<RG* AO<UO*
Games per set	**.004**	**.017**	.236	AO>UO* RG>UO**	
Points per game	.885	**.000**	**.000**		AO<RG*** AO<UO**
Variables related to serve points					
Aces	**.000**	**.002**	.609	AO>UO** RG>UO*	
Double faults	**.001**	**.023**	**.000**		
R. Aces/Double faults	**.000**	**.002**	.139	AO>UO*	
Points played on first serve	.449	**.010**	**.017**	RG>UO*	
Total points played on serve	.065	.350	**.002**	AO>UO*	AO<UO*
First serve (%)	.088	**.000**	.305	AO>RG* RG>UO***	
Points won on first serve	**.023**	.597	.856		
Points won on first serve (%)	**.000**	**.000**	**.000**		
Points won on second serve	**.000**	**.001**	.138	AO>UO** RG>UO***	AO<UO** RG<UO*
Points played on second serve	.055	**.038**	**.003**	AO>UO* RG>UO***	AO<UO*
Points won on second serve (%)	**.010**	**.028**	.342		
Variables related to return points					
Break points won	**.000**	**.000**	**.003**		
Break point opportunities	**.002**	**.000**	**.002**		
Break points won (%)	**.020**	.144	.660		
Receiving points won	.057	**.000**	**.000**		
Receiving points played	.075	.434	**.002**	AO>UO* RG>UO*	AO<UO*
Receiving points won (%)	**.000**	**.000**	**.002**		
Total points won	.268	.273	**.003**	AO>UO* RG>UO*	

Legend: CT: Conventional Tennis; WT: Wheelchair Tennis; AO: Australian Open; RG: Roland Garros; UO: US Open. Statistical differences (Mann Whitney U): *p<.05; **p<.01; ***p<0.001.

The means (M) and standard deviation (SD) of set statistics in conventional tennis (CT) and wheelchair tennis (WT) for the analysed women's Grand Slam Tournaments are demonstrated in Table 4.

Table 4. Descriptive statistics for women's CT and WT sets

	Australian Open				Roland Garros				US Open			
	CT		WT		CT		WT		CT		WT	
Variables	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Variables related to match												
Total match time	40.25	12.93	31.69	6.85	34.50	5.59	33.53	7.51	46.06	13.20	40.47	13.94
Total points played	57.88	18.07	55.75	9.51	50.67	8.24	56.80	15.39	64.33	16.13	63.27	18.89
Games per set	8.75	2.31	8.25	1.27	8.08	1.14	8.07	1.14	9.72	2.19	9.60	2.16
Points per game	6.59	.92	6.81	1.01	6.28	.65	7.02	1.43	6.63	.85	6.52	.71
Variables related to serve points												
Aces	.63	.91	.59	.84	2.04	1.78	.37	.56	.58	.84	.27	.45
Double faults	1.47	1.29	3.13	2.20	1.08	1.10	3.90	3.02	1.64	1.50	3.93	2.61
R. Aces/Double faults	.44	.63	.22	.34	1.70	1.80	.14	.37	.30	.51	.09	.20
Points played on first serve	17.31	6.49	17.34	6.24	15.67	3.69	16.60	6.48	21.19	5.98	18.37	6.89
Total points played on serve	28.94	9.90	27.87	7.55	25.33	5.51	28.40	9.92	32.14	8.83	31.63	10.14
First serve (%)	60.46	11.12	61.63	12.97	62.61	10.98	58.24	10.94	66.61	10.08	57.28	8.15
Points won on first serve	10.53	4.49	9.94	4.18	9.46	3.26	9.37	5.11	12.94	4.56	9.63	4.87
Points won on first serve (%)	60.85	14.93	57.26	14.10	60.78	19.97	55.76	15.28	60.66	12.92	51.25	18.51
Points won on second serve	5.00	2.85	3.78	2.20	4.71	1.81	4.73	2.29	4.28	2.71	4.27	1.96
Points played on second serve	11.63	5.25	10.53	4.14	9.67	3.80	12.10	4.82	10.94	4.76	13.27	4.24
Points won on second serve (%)	43.65	20.30	35.30	18.20	50.35	12.28	41.28	19.95	38.85	18.71	32.77	13.42
Variables related to return points												
Break points won	1.72	1.14	2.09	1.17	1.50	1.14	2.33	1.45	2.06	1.17	3.07	1.36
Break point opportunities	3.69	2.16	3.87	1.98	3.54	2.48	4.67	2.63	4.39	2.21	5.47	2.29
Break points won (%)	40.94	29.17	60.49	32.85	39.29	32.74	46.82	25.36	47.84	26.67	58.08	24.63
Receiving points won	13.41	5.64	14.16	4.32	11.17	4.20	14.30	5.87	14.92	4.40	17.73	6.09
Receiving points played	28.94	9.90	27.88	7.55	25.33	5.51	28.40	9.92	32.14	8.83	31.63	10.14
Receiving points won (%)	46.01	14.23	51.50	11.86	44.22	14.92	50.51	15.48	47.07	10.59	56.63	13.18
Total points won	28.94	10.61	27.88	6.88	25.33	6.90	28.40	9.85	32.17	9.22	31.63	10.61

Legend: CT: Conventional Tennis; WT: Wheelchair Tennis; R: Ratio.

The statistical differences in women's sets between modalities (CT and WT) and tournaments (AO, RG, and UO) are shown in Table 5. Data express the p-value and the tournament where significant differences were found.

Table 3. Statistical differences in game statistics for women's sets between modalities and tournaments

	Modalities (CT vs. WT)			Tournament	
	AO	RG	UO	CT	WT
Variables related to match					
Total set time	**.003**	.507	.116	AO>UO* RG>UO***	AO<UO**
Total points played	.914	.125	.836	AO>UO***	
Games per set	.806	.971	.852	AO>UO**	AO<US* RG<UO**
Points per game	.390	**.015**	.570		
Variables related to serve points					
Ace	.970	**.000**	.163	AO<RG*** RG<UO***	
Double faults	**.000**	**.000**	**.000**		
R. Aces/Double faults	.431	**.000**	.177	AO<RG *** RG<UO***	
Points played on first serve	.742	.787	.076	AO<UO** RG<UO***	
Total points played on serve	.909	.448	.802	RG<UO**	
First serve (%)	.481	.280	**.000**		
Points won on first serve	.746	.523	**.008**	AO<UO* RG<UO**	
Points won on first serve (%)	.271	.222	**.021**		
Points won on second serve	.080	.826	.696		
Points played on second serve	.492	.114	**.041**		AO<UO**
Points won on second serve (%)	.102	**.006**	.174	RG>UO	
Variables related to return points					
Break points won	.273	**.031**	**.002**		AO<UO** RG<UO
Break point opportunities	.902	.122	**.040**		AO<UO**
Break points won (%)	**.017**	.206	.107		
Receiving points won	.647	**.030**	.059	RG<UO**	AO<UO** RG<UO*
Receiving points played	.909	.448	.802	RG<UO**	
Receiving points won (%)	.119	.077	**.002**		
Total points won	.722	.272	.772	RG<UO**	

Legend: CT: Conventional Tennis; WT: Wheelchair Tennis; AO: Australian Open; RG: Roland Garros; UO: US Open; R.: Ratio. Statistical differences (Mann Whitney U): *p<.05; **p<.01; ***p<0.001.

DISCUSSION

The purpose of the study was to analyse the differences in game statistics between conventional tennis (CT) and wheelchair tennis (WT) in three 2014 Grand Slam tournaments played on different surfaces and with different types of balls. The results show differences between CT and WT and between the different tournaments. These findings show that the criteria to analyse CT are different than WT regarding game statistics and variables related to the serve and the return. This idea is also applicable between the different tournaments; although for some variables, similarities are found between tournaments.

Differences were found in all variables between WT and CT in some of the tournaments. These data show an important variability in game statistics between WT and CT for different tournaments. Previous studies have assessed the differences in match statistics between surfaces in CT matches [5,14] and in WT matches [13]. The present results are similar to findings of previous studies. These data show the impact of the surface and ball type on the game's demands, and these aspects are only some of the factors that affect game statistics. These two aspects, surface and ball type, must be considered in the analysis and training of CT and WT players. Four of the studied variables between CT and WT were significantly different in all the tournaments. CT players had a higher percentage of points won on first serves and fewer double faults, break points won, and break point opportunities than WT. This seems to suggest that the serve has less impact on the game in WT than CT. The reason for this lower impact could be that WT players are seated and their contact point is lower than standing players [15], so it is more difficult to execute a serve with higher angles of incidence. Additionally, WT players serve slower than CT players [12] making it even more difficult to win serve points. This finding confirms previous studies, where the percentage of points won on first and second serves in WT (61% and 42%, respectively) was found to be lower than in CT (71% and 51%, respectively) [4,13]. These differences in the serve are the reasoning for the variance found in at least two of the tournaments, such as the higher number of aces and points won on the second serve and the lower number of receiving points won in CT. Data show the relationship between the serve and the return is more balanced in WT than in CT. These data could be related to the low number of shots per rally in WT between 2-4 shots [16-19], which confirms the idea that serves and return shots are more important in WT than in CT.

These tendencies were not found for women. Female players only presented a higher occurrence of double faults and break points won in WT than in CT. These values could be due to the lower impact of the serve in the women's game than in the men's game as happens in CT [14]. Physical and anthropometric differences could be the reason for these tendencies. Additionally, in CT, female players serve slower than male players [20,21] and this could be extrapolated to the seated situation. Data show more similarity for female CT and WT players' actions in the different tournaments than for the male players' actions. When grouping the tournaments, the AO can be differentiated from RG and the UO. For RG and the UO, a similar tendency to the one described for men can be observed for women. In these tournaments, a higher proportion of aces and points won with the first serve and fewer break points were found. More studies are needed to understand the reason for these differences between tournaments.

Regarding the impact of the characteristics of the tournament (i.e. surface and ball type) in CT, for men, similar characteristics were found in percentage of points won on first and second serves and percentage of receiving points won in all tournaments, as previous studies also found [14]. The sets of AO and RG are slower than in the UO. This can be observed in the lower total set time, points played, and games per set in these tournaments. This finding shows a higher imbalance between players in these tournaments (AO and RG). Surprisingly, the UO is played on a faster surface, and there are fewer aces than in the AO or RG, contrary to other studies [5]. This may be due to the type of sample studied in the present study (i.e. eight best players of each tournament). These best players of each tournament could have specific characteristics (e.g. playing style or anthropometry) that do not allow them to get more aces. Also, it is possible that in this type of confrontation (players level) the game's performance indicators change. Most previous studies have analysed the average values of the players or the differences between winning and losing. Future studies are needed to assess this aspect. Differences in percentage of first serve (table 3) between the AO and RG compared to the UO could be explained similarly.

For women, the data show different tendencies in CT than for men. In the UO (medium-fast pace), there were higher occurrences of aces, ratio of aces/double faults, and points won on first serve than in RG or the AO (slow and medium pace, respectively). Data of set statistics are similar to those found in previous studies [5]. For RG, more points won on second serves and fewer receiving points won were found than in the UO. This differs from

previous studies, where the values were similar on all surfaces [5]. These differences could be due to the characteristics of the best eight players.

Regarding the effect of the characteristics of the tournament (i.e. surface and ball type) in WT, the findings show different tendencies than in CT. No clear differences were found for the serve and return actions in the different tournaments. These data show that the tournament's characteristics affect the ways these actions are executed less in WT than in CT. These tendencies were found for men and women. Men scored more points on the second serve, specifically, in the UO. For women in WT matches, players scored more break points and more receiving points on faster surfaces (UO) than on medium and slow surface (AO and RG). This may be due to a higher total set time and more games per set in the UO than other tournaments. This seems to suggest that the UO is a more competitive tournament than RG or the AO.

Data show that CT and WT are different and that they require specific criteria and reference values to guide their analysis and training. The differences in the role of the serve, the importance of the return actions, or the efficacy percentage must be considered when working with WT players. To properly interpret the data from this study, it must be kept in mind that only the eight best players of CT were analysed, and the WT players' anthropometric characteristics, playing style, and type of injury were not analysed. More studies are needed in WT to provide objective values for researchers, managers, and coaches. Another aspect to consider in order to adjust the players' training to the game's demands is the characteristics of the tournament. Data show variations in the importance of the various aspects of the game that were studied and the values of these variables. Further studies are needed to determine the reason for these differences, the characteristics of the players that reach the quarterfinals in these tournaments, and the characteristics of the tournament. This paper provides values that could help us to understand and analyse the game and could be used by coaches in the design of real game-like situations in practice. Future studies need to analyse the way technical and physical actions are done by the players, not just the outcome of their actions. These data are needed for both sexes and for the different stages of development of the WT players.

CONCLUSION

CT players have better performance in serve situations than WT players. On the other hand, WT players have better performances in return situations than CT players. The values between CT and WT for female players are more balanced than for male players. Regarding the court surface, more differences in game statistics are found for CT than WT for both genders. All these data can be used by tennis coaches to understand the needs of each modality and to help in training sessions through goal setting.

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IV

Match analysis of women´s wheelchair tennis matches for the Paralympic Games

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Match analysis of women´s wheelchair tennis matches for the Paralympic Games

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Abstract

The purpose of this study was to determine the differences between winning and losing a wheelchair tennis match in the 2012 Paralympic Games. Data from 67 sets of 32 matches played by 32 female players in the 2012 Paralympic Games were analysed. The variables were grouped into four groups: variables related to the serve, to the return, to winners and errors, and variables related to net points. Univariate (Wilcoxon test) and multivariate (discriminant) analyses of data were carried out to discriminate the result of the set (win or loss). The variables that best predict the result of the set are break points won and points won on the first serve. The results showed that the winning player is a more aggressive server and serve returner, achieves more winning shots than her opponent, and commits fewer errors during the match. The paper discusses the differences between conventional tennis and wheelchair tennis and the application of the results.

Key words: Notational analysis, match analysis, racket sports, performance indicators.

1. Introduction

Wheelchair tennis (WT) is an adapted sport. For it to be able to develop, more information is needed with regards to player profiles, game situations, game styles, stroke production and mobility within wheelchair tennis. This is essential information to be able to provide coaches and players with information in order to achieve the high performance required. There are several studies of WT related to physiology (Barfield et al., 2009; Croft et al., 2010; Diaper and Goosey-Tolfrey, 2009; Goosey-Tolfrey and Moss, 2005; Sindal, et al., 2013), social or psychological issues (Greenwood et al., 1990), injury prevention (Reid et al., 2007), and motor control (Reina et al., 2007), but there are only a few studies that analyse real game situations (Filipcic and Filipcic, 2009; Sanchez-Pay et al., 2013). Players use different strategies and tactical intentions

to maximise their chances of winning a match. The strategies are based on knowledge of their own strengths and weaknesses, as well as those of their opponent (O'Donoghue and Ingram, 2001). This process is common in competitive sports (Hughes and Barlett, 2002; O'Donoghue, 2005).

No studies have been found in our bibliography review related to winning or losing women´s WT matches. A statistical analysis of match characteristics allows for a deeper understanding of winning or losing a match (Filipcic et al., 2011). The study of match reports can be an important resource in order to discover patterns in opponent play. This knowledge may assist the decision making of coaches and players (O'Donoghue, 2007) and will provide them with profiles to analyse the match reports.

Due to the limited existing research on real game situations in WT, the training systems have been based on studies of conventional tennis (CT). Conventional tennis studies can serve as a limited guide for WT training. This is due to WT rules and players´ characteristics differing from CT. For example, in WT, the ball can bounce twice before a player hits (ITF, 2012). This acts to compensate for lower player mobility, as players are seated in a wheelchair and carrying a racquet (Goosey-Tolfre and Moss 2005). Thus, the contact height will be lower than in CT, making it difficult, especially for serving (Sanz, 2003). In addition, players with different injuries can play in the same category. This means that two players with different functional mobility can play together. This is one aspect to take into consideration when understanding competition (Barfield, et al., 2009).

There are very few studies related to competition statistics in adapted sports, and they are focused on team sports such as ice sledge hockey (Häyrinen, et al., 2001), wheelchair rugby (Morgulec-Adamowicz, et al, 2010), and wheelchair basketball (Gomez et al., 2014; Molik, et al., 2009). We have only found one study that compared competition statistics on different playing surfaces and that was in men's WT (Sanchez-Pay, et al., 2013). The scarce information that is available regarding women´s WT means coaches use subjective information, either applying information from CT or from men´s WT. However, it is not clear whether this information is applicable to female players. More knowledge about athletes' performance can help improve the quality of play and will assist coaches in the development of this specific sport. The aim of this study was to analyse the differences in game statistics of women´s WT matches with regards to winning and losing.

2. Method

2.1. Samples

Sixty-seven sets of 32 women´s singles matches from the 2012 Paralympic Games in the WT competition were analysed. All the matches were played on the same surface (hard court). Thirty-two female players played in the open division and were included in the study. The unit of analysis was the set to prevent winning and losing sets to counteract each other in 3-set matches. The participants classified for the competition through the following criteria: 22 were the best internationally ranked players of the ITF ranking, one was the winner of the Pan-American games, one was the winner of the

Asian games, and eight were wildcards from the International Paralympics Committee and the International Tennis Federation. No more than four players from the same country and sex could participate in the WT competition. The data were collected from the official website of the Paralympic Games (accessed on 13th October 2012). All matches were played according to WT rules (ITF, 2012). Unfinished matches were not included in the database. Variables were divided into four groups: those related to the serve, return, winners and errors, and variables related to net points (Table 1).

Table 1. Variables studied in the WT competition from the 2012 Paralympic Games in London.

Group of variables	Game statistics
Variables related to serve points	Total aces, double faults, points played on first serve, total points played on serve, percentage of first serves, aces on first service, aces on second service, points won on first serve, percentage of points won on first serve, points played on second serve, points won on second serve, and percentage of points won on second serve.
Variables related to return points	Receiving points won, receiving points played, percentage of receiving points won, break points won, break point opportunities, percentage of break points won, and returns of serve winners.
Variables related to winners and errors	Total winners, forehand winners, backhand winners, forced errors, unforced errors, and total points won.
Variables related to net points	Net points won, net points played, and percentage of net points won.

Note: Data were obtained from the official statistics of the Paralympic Games (http://www.london2012.com/paralympics).

The data were collected in a specifically designed spreadsheet (Microsoft Excel) and were then exported to the SPSS 19.0 statistical program for analysis. Data were analysed by set.

2.2. Statistical analysis

Firstly, a descriptive analysis of the data (means and standard deviation) was done. A Wilcoxon test (non-parametric) was carried out with the aim of analysing the differences between winning and losing each set, because the assumptions of normality and homogeneity of variances were not satisfied. To find those statistical variables that best differentiate the two groups (winning and losing players), a discriminant analysis (Ntoumanis, 2001) was conducted. For the interpretation of the linear vectors, an SC (Structural Coefficient) >0.30 was considered relevant. Significance was set at $p<0.05$.

3. Results

With regard to serve point variables (table 2), winning players had significantly higher values for the following variables: points won on first serve [$Z=-5.747$, $p < 0.001$], percentage of points won on first serve [$Z=-6.682$, $p < 0.001$], points won on second serve [$Z=-4.361$, $p < 0.001$], and percentage of points won on second serve [$Z=-6.107$, $p < 0.001$]. On the other hand, losing players had significantly more double faults [$Z=-2.751$, $p = 0.006$]. With the exception of points played on the second serve, winning players had higher values for all variables although no significant differences were found.

Concerning return point variables, winning players had significantly higher mean values

for the following variables: percentage of receiving points won [Z=-3.339, p = 0.001], break points won [Z=-7.064, p < 0.001], break point opportunities [Z=-5.747, p < 0.001], percentage on break point won [Z=-4.437, p = 0.001] and return winners [Z=-3.734, p < 0.001]. No significant differences were found for receiving points won [Z=-1.884, p = 0.06] or receiving points played [Z=-0.105, p = 0.917].

For the variables related to winners and errors, significant differences were found for all variables. Winning players had significantly higher averages for the following variables: total winners [Z=-5-961, p < 0.001], forehand winners [Z=-5.934, p < 0.001], backhand winners [Z=-3.471, p = 0.001], and total points won [Z=-7.116, p < 0.001]. Losing players had significantly higher averages for forced errors [Z=-5.783, p < 0.001] and unforced errors [Z=-2.591, p < 0.05]. For the net point variables, winning players had significantly higher mean values for all variables: net points won [Z=-2.728, p < 0.01] and percentage of net points won [Z=-3.797, p < 0.001].

The multivariate analysis showed that the discriminant function obtained was significant (p < 0.001), and it correctly classified 96.5% of winning and losing players (Table 3). The variables that best differentiate winning and losing players were percentage of points won on the first serve (SC = 0.568) and break points won (SC = 0.531).

Table 2. Differences between winning and losing players in game statistics from the 2012 Paralympic Games in London.

	WINNING PLAYERS		LOSING PLAYERS		P[1] value	Z value
Variables	M	SD	M	SD		
Variables related to serve points						
Total aces	.69	.99	.42	.65	.071	-1.805
Double faults	2.61	2.03	3.54	1.92	.006	-2.751
Points played on first serve	16.49	7.11	15.60	7.79	.221	-1.225
Total points played on serve	26.94	10.79	26.82	10.04	.791	-0.265
First serve (%)	61.73	11.23	56.76	15.38	.071	-1.805
Aces on first serve	.55	.84	.36	.60	.170	-1.372
Aces on second serve	.13	.46	.06	.24	.285	-1.069
Points won on first serve	11.07	3.80	7.13	4.76	.000	5.747
Points won on first serve (%)	70.53	14.36	43.25	15.36	.000	6.682
Points won on second serve	5.01	2.60	3.13	2.20	.000	-4.361
Points played on second serve	10.31	5.02	11.22	4.77	.203	-1.273
Points won on second serve (%)	50.92	18.72	26.43	14.37	.000	-6.107
Variables related to points return						
Receiving points won	14.67	6.37	12.60	7.99	.060	-1.884
Receiving points played	26.82	10.04	26.81	10.78	.917	-0.105
Receiving points won (%)	54.98	15.55	43.68	16.82	.001	-3.339
Break points won	3.13	.69	1.09	1.14	.000	-7.064
Break point opportunities	5.34	2.25	2.66	2.63	.000	-5.747
Break points won (%)	66.49	23.37	49.12	33.26	.000	-4.437
Return of serve winners	3.87	2.89	2.21	2.29	.000	-3.734
Variables related to winners and errors						
Total winners	12.55	5.04	6.64	4.76	.000	-5.961
Forehand winners	8.04	3.93	3.87	3.13	.000	-5.934
Backhand winners	3.28	2.33	2.12	2.25	.001	-3.471
Forced errors	8.31	5.43	12.66	4.78	.000	-5.783
Unforced errors	6.03	3.53	7.43	3.18	.010	-2.591
Total points won	32.64	7.37	20.99	11.32	.000	-7.116
Variables related to net points						
Net points won	1.43	1.44	.81	1.25	.006	-2.728
Net points played	2.12	1.93	1.90	2.18	.408	-0.827
Net points won (%)	70.41	32.90	38.46	34.69	.000	-3.797

Table 3. Standardised coefficients from the discriminant analysis of the game statistics between winning and losing female players in the 2012 Paralympic Games.

Game statistics variable	**Winning-Losing**
Points won on first serve (%)	.568*
Break points won	.531*
Break point opportunities	.229
Net points won (%)	.202
Total winners	.195
Forced errors	-.194
Net points won	.172
Backhand winners	.170
Double faults	-.138
First serve (%)	-.137
Points won on first serve	.133
Unforced errors	-.130
Forehand winners	.123
Total points won	.123
Receiving points won (%)	.122
Break points won (%)	.106
Points won on second serve (%)	.103
Points won on second serve	-.100
Return of serve winner	.085
Receiving points played	-.052
Aces on first serve	.050
Total aces	.050
Points played on first serve	-.042
Net points played	-.030
Total points played on serve	-.024
Receiving points won	.019
Aces on second serve	.012
Points played on second serve	.007
Eigenvalue	3.06
Wilks' Lambda	.24
Canonical Correlation	.86
Chi-square	114.22
Significance	.00
Reclassification	96.5%

* SC discriminant value ≥|.30|

4. Discussion

The purpose of this study was to analyse the statistical differences between winning and losing in women´s WT. Winning players have better serve performances. They win more points with their first and second serves than their opponents. This may be due to winning players having better serving skills than losing players, with superior spins, direction, and power, similar to what occurs in CT (Gillet et al., 2009). These data are

slightly lower than male professional wheelchair players (Sanchez-Pay, et al., 2013). This may be due to female players having less hit speed on the serve than male players, as happens in CT (Cross, 2014; Miller, 2006).

More points are won on the first and second serves in women´s wheelchair tennis than in the women´s conventional game (70% vs 62% and 50% vs 45%, respectively) (Barnett et al., 2008; Brown and O'Donoghue, 2008). Winning players in both WT and CT win approximately 25% more points with their first and second serves. These differences may be due to several aspects of the game such as higher technical and tactical awareness regarding the serve, as occurs in CT (Gillet, et al., 2009). It may also relate to the kind of injury a player has. This influences the serve, including the point of impact and the level of functional mobility of the execution. This may allow players to hit the ball in the serve with a greater angle and affect the return capacity of the opponent (Sanz, 2003).

In relation to the number of aces and double faults, winning players serve more aces and have fewer double faults per set compared to their losing counterparts. These data are worse when compared to previous studies in men´s WT (Sanchez-Pay, et al., 2013) and women´s CT (Filipcic, et al., 2011). Women´s WT players executed fewer aces and more double faults than men´s WT and women´s CT players. The ratio of aces to double faults for winning players in women´s WT is 1 : 3.83 and for winning players in women´s CT is 1 : 1.01. For losing players in women´s WT, it is 1 : 8.42, and for losing players in women´s CT, it is 1 : 4.50 (Filipcic, et al., 2011). This demonstrates the difficulty for female wheelchair players to win points on serve, possibly due to their lower seated position relative to CT players (Sanz, 2003). However, the differences between winning and losing players provide us with useful information to guide training and competition through goal-setting exercises (e.g. acceptable serving values). Serving is directly related to return. The data show that the percentage of receiving points won is significantly higher for the winning players than the losing players. Furthermore, winning players make more return winners than losing players. This may indicate that winning players are more aggressive than losing players in the return situation. This may be due to winning players making the return shot after the first bounce and losing players doing so after the second bounce, but this consideration has not been taken into account in this study. In relation to CT, there are differences in the number of receiving points won, with higher values for WT players when compared to women´s professional tennis players on hard courts (Barnett, et a., 2008) and clay courts (Filipcic et al., 2008). These differences reflect a greater opportunity for the WT players to win points in the receiving situation in comparison to CT. This may be due to two factors: firstly, that the serving player is in a static position after the serve making it difficult to retrieve the return (Sanz, 2003); and secondly, that the winning players are more aggressive and intent on taking the lead in the point.

These results show that winning players achieve more opportunities to break serve than losing players. This is because winning players have more receiving points won, making it more likely that players break serve. In women´s CT, the values are lower than in this study (Filipcic, et al., 2008, 2011). These differences show that WT players are more likely to break serve than CT players.

Winning players hit twice as many winning shots per point and winning points than losing players. These data may be due to winning players having better tactical awareness in shot execution (direction, distance, spin, and power) and/or wheelchair movement (recoveries, movement speed, and position), aspects which were not evaluated in this study. For women´s CT, the ratio of winners to shots is higher (Filipcic, et al., 2008) than in women´s WT. Data suggest that although the ball can bounce twice before being hit for WT players, their decreased ability does not allow them to return the opponents´ winning shots as in CT. As with multiple sprint-based wheelchair sports, the WT player's ability to accelerate quickly from a standstill is considered more important than maximum velocity (Vanlandewijck et al., 2001). From a general perspective, the data show that in WT, there are more winning shots than in CT. Furthermore, in both WT and CT winning players execute more winners than losing players (Filipcic, et al., 2008; Katic et al., 2011).

The univariate analysis demonstrated that significant differences exist in more than half of the analysed variables, but the discriminant analysis determines which variables better represent the difference between winning and losing. The discriminant analysis demonstrated that the number of statistically significant variables was two (percentage of points won on first serve and break points won); one in a serving situation and the other in a returning situation. Thus, for a player to win a set, he or she must break the serve of his/her opponent and have a high percentage of points won on his/her own first serve.

Female WT players have a better chance of winning if their serves hinder the receiver, so they may win points and take the initiative by winning a high percentage of both first and second service points. Similarly, for the return situation, WT players are more successful, winning more points compared to CT players. While this may seem obvious, in the case of WT, it is pertinent because the possibilities of producing a good serve are affected by the seated position in the chair and the kind of injury.

Winning players are more aggressive servers and returners and produce more winning shots than their opponents. This results in fewer errors throughout the match. All data are affected by the kind of injury the players may have. A higher degree of injury will hinder one's ability to hit the ball higher (e.g. serve) (Sanz, 2003). Similarly, an injury leading to less functional mobility will cause the player to be less mobile around the court and, thus, slower in comparison to another player with greater mobility (Goosey-Tolfrey and Moss, 2005).

Wheelchair tennis is an adapted sport which has grown much in the last decade (Bullock and Sanz, 2010). In search of professionalism, it is necessary to know what the differences are between winning and losing a match. The aim of this study was to compare the differences in match statistics between winning and losing. This study concludes that winning players have a greater tactical awareness of serve and return situations than losing players. Winning players have a higher percentage of points won on first and second serves as well as return and break points won. The winning women´s WT player is the more offensive player and safer in their play than the losing player, due to having a greater number of winning shots and fewer errors. Due to the fact that it is an adapted sport, players may have different injuries, which hinder them to

a different degree in their match play. It is not a game between equals. The differences in the degree of functional mobility between players can affect performance, as in other sports, such as basketball (Vanlandewikcj, et al., 2007). Thus, players with a lower degree of injury have better individual performances. These data may contribute to a better understanding of this sport. The results will help the coach to prepare and design training sessions according to the real needs from match situations.

Future studies are needed to verify the aspects discussed that differentiate those players who win and lose as well as with CT. The goal of this study was to provide a general profile of winning players in order to have values to contextualise women´s WT and to analyse peak performance by players. The present study analysed women´s WT from a general perspective. However, further work is needed to study the way that women´s WT players play (tempos, players´ and ball speeds, zone, manner of executions, bounces, moment of the match, etc.). These studies must also consider types of player injury and players´ anthropometrical and physical characteristics.

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V

Differences in game statistics between winning and losing male wheelchair tennis players in 2012 Paralympics Games

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Differences in game statistics between winning and losing male wheelchair tennis players in 2012 Paralympics Games

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Abstract

The aim of the present study was to analyze the differences in wheelchair tennis game statistics between winning and losing players. Data from 139 sets of 64 matches played by 64 males' players in the 2012 Paralympics Games were analyzed. The variables studied were grouped in four groups: variables related to serve, to return, to winners and errors, and to net point. Data was collected from official website of the Paralimpics Games. An univariate (Mann Whitney U) and multivariate (discriminant) analysis of data was done to the study the four groups of variable in relation to the result of the set (win or lose). Winning players had significantly higher average of number of total aces, percentage of first serves, points won on first and second serve, receiving points won, break points won, break point opportunities, return of serve winners, total winners, forehand and backhand winners, net points won, net points played, and total points won. Losing players had significantly higher averages for the variables double faults, points played on second serve, forced errors, and unforced errors. The variables that best predict the result of the set are break points won and points won on first serve. The result showed that winning players do less errors and play more offensive with their serve than loser players; and win more no-break points and break point. The value presented could be used as a reference for practice and competition in peak performance wheelchair tennis players.

Keywords

Notational analysis, match analysis, racket sports, performance indicators.

Introduction

Match analysis is an area of sports science and describes the analysis of sports competition. In the case of tennis, using match statistics data, it is possible define better player's performance at level of individual characteristics (O'Donoghue, 2012), winning or losing (O'Donoghue & Ingram, 2001), way of playing on different surfaces (Barnett, Meyer, & Pollard, 2008; Cross & Pollard, 2009), or against different opponents (right and left handers) (Loffing, Hagemann, & Strauss, 2010). A statistical analysis of match characteristics allows us to deepen in the knowledge and reasons for winning or losing a match (Filipcic, Caks, & Filipcic, 2011). There is not much information about the tactical wheelchair tennis competition, so the training system is based in the research information from conventional tennis. In that sense there is a lack of information about this notational analysis of wheelchair tennis real game situation, who help us to know more about the main reasons to win or lose a match from a statistical point of view.

The main difference compared to conventional rules tennis and wheelchair tennis is that the ball can bounce twice before being hit (ITF, 2012). This rule allows players to hit balls far as its ability to displacement from conventional tennis is lower (Sanz, 2003). The displacement capacity is determined largely by the type of injury the player, so players with less severe injury will be faster than players with a more severe injury (Goosey-Tolfrey & Moss, 2005). The type of injury will allow the player to sit higher or lower in his chair, although the height of hit the ball will always be lower than a conventional tennis player (Sanz, 2003). This lower position the wheelchair tennis player, could affect the action mainly serve, performing as many double faults and fewer aces (Sanchez-Pay, Torres-Luque, Fernandez-Garcia, & Sanz-Rivas, 2013). These differences with conventional tennis influence could affect in the dynamics of the game. Therefore, the aspects and the values that differentiate winning players from the losers in conventional tennis, such as numbers of aces, double faults, errors, point won on first and second serve, winner, break points won, etc. (Katic, Milat, Zagorac, & Durovic, 2011), could not be applicable in wheelchair tennis. The aim of the present study was to analyze the differences in game statistics of wheelchair tennis between winning and losing players.

Methods

Data from 139 sets of 64 single male matches played on the 2012 Paralympics Games were analyzed. All the matches were played on hard court. The sample represents 100% of all matches played by 64 male players. In this tournament played the best international ranking players with

qualifying through competition system. Data for the study were gathered from the official website of the Paralympics Games (accessed 13th October 2012). All matches were played best of three set with tie break in all sets. The criteria for matches to be included in the study were that the match had to be a completed match. The studied variables were divided into four groups (Table I).

Table I. Variables studied in the wheelchair tennis competition from the Paralympics Games London 2012.

Group of variables	Variables or game statistics or performance indicators
Variables related to points serve	Total aces, double faults, points played on first serve, total points played on serve, percentage of first serves, aces on first service, aces on second service, points won on first serve, percentage of points won on first serve, points played on second serve, points won on second serve and percentage of points won on second serve.
Variables related to points return	Receiving points won, receiving points played, percentage of receiving points won, break points won, break point opportunities, percentage of break points won, and returns of serve winners.
Variables related to winners and errors	Total winners, forehand winners, backhand winners, forced errors, unforced errors, and total points won.
Variables related to net points	Net points won, net points played and percentage of net points won.

Note: Data was obtained from the official statistics of the Paralympics Games (http://www.london2012.com/paralympics).

The data were obtained from the official statistics of the tournament. The data were recorded onto a specifically designed data collection form before being entered into spreadsheet for processing. The unit of analysis was the set. From the spreadsheet, data was exported to SPSS 18.0 for its analysis.

Statistical analysis

Firstly, a descriptive analysis of the data was done (average values and standard deviations). Secondly, a Mann-Whitney U (non-parametric) was carried out with the goal of analyzing the differences between winning and losing players. Finally, a discriminant analysis (Ntoumanis, 2001) was done to find those statistical variables that best differentiate winning and losing players. Structural Coefficients (SC) greater than or equal to |.30| (Tabachnick & Fidell, 2001) was considered relevant for the interpretation of the linear vectors. All of the statistical analyses were done with a level of significance of $p \leq 0.05$.

Results

Regarding to point serve variables (Table II), winning players had significantly higher values for the following variables: total aces [Z=-5.121, p < 0.001], percentage of first serve [Z=-2.820, p<0.05], aces on first serve [Z=-5.153, p < 0.001], points won on first serve [Z=-7.336, p < 0.001], percentage of points won on first serve [Z=-12.025, p < 0.001], points won on second serve [Z=-3.908, p < 0.001], and percentage of points won on second serve [Z=-8.933, p < 0.001]. On the other hand, losing players had significantly higher values for the variables: double faults [Z=-3.723, p<0.001], and points played on second serve [Z=-2.984, p<0.01], and non significantly for the points played on serve [Z=-1,289, p=0.198]. For the rest of variables, no significant differences were found.

For the return points variables, winning players had significantly higher averages values in the following variables: receiving points won [Z=-5.432, p < 0.001], percentage of receiving points won [Z=-7.731, p < 0.001], break points won [Z=-12.481, p < 0.001], break point opportunities [Z=-8.874, p < 0.001], percentage of break points won [Z=-5.220, p < 0.001], and returns on serve winners [Z=-6.335, p < 0.001]. No significance differences were found in the variable receiving points played [Z=-1.165, p = 0.244].

For the winners and errors points variables, significantly differences were found in all variables. Winning players had significantly higher averages for the following variables: total winners [Z=-8.213, p < 0.001], forehand winners [Z=-7.500, p < 0.01], backhand winners [Z=-4.751, p < 0.001], and total points won [Z=-9.459, p < 0.001]. Losing players had significantly higher averages for the variables forced errors [Z=-7.419, p < 0.001], and unforced errors [Z=-3.758, p < 0.001]. For the net points variables, winning players had significantly higher averages values in all variables: net points won [Z=-3.698, p < 0.001], net points played [Z=-2.461, p < 0.05], percentage on net points won [Z=-2.569, p < 0.05].

The multivariate analysis showed that the discriminant function obtained was significant (p < 0.001), and it correctly classified 99.6% of winning and losing players (Table III). The variables which allow us to discriminate better the category winners or losers were the break points won (SC = 0.35), and percentage of points won on first serve (SC = 0.35).

Table II. Differences between winning and losing wheelchair tennis players in game statistics from the 2012 Paralympics Games. Media (M) and Standard Deviation (SD).

	LOSER SET		WINNER SET		p[1] value
Variables	M	SD	M	SD	
Variables related to points serve					
Total aces	.54	.92	1.18	1.23	.000
Double faults	2.37	1.77	1.63	1.52	.000
Points played on first serve	17.12	7.12	17.32	6.71	.743
Total points placed on serve	27.48	9.06	26.12	8.86	.198
First serve (%)	61.72	12.62	66.20	12.11	.005
Aces on first serve	.47	.81	1.08	1.17	.000
Aces on second serve	.06	.27	.10	.33	.261
Points won on first serve	8.40	4.72	12.05	3.60	.000
Points won on first serve (%)	47.17	14.22	72.50	12.94	.000
Points won on second serve	3.51	2.36	4.58	2.26	.000
Points played on second serve	10.40	4.49	8.82	4.17	.003
Points won on second serve (%)	32.01	17.12	53.74	19.02	.000
Variables related to points return					
Receiving points won	10.67	6.16	14.47	5.71	.000
Receiving points played	26.23	9.05	27.40	9.06	.244
Receiving points won (%)	38.51	14.51	53.22	14.30	.000
Break points won	.80	.96	2.73	.73	.000
Break points opportunities	2.35	2.41	5.06	2.27	.000
Break points won (%)	40.52	33.83	61.28	22.75	.000
Return of serve winners	1.53	1.73	3.05	2.30	.000
Variables related to winners and errors					
Total winners	7.42	4.84	12.55	4.98	.000
Forehand winners	3.80	2.74	6.68	3.11	.000
Backhand winners	2.54	2.41	3.77	2.41	.000
Forced errors	12.85	4.41	8.72	5.04	.000
Unforced errors	6.47	3.65	5.12	3.91	.000
Total points won	21.51	9.99	32.19	6.09	.000
Variables related to net points					
Net points won	1.58	1.82	2.46	2.16	.000
Net points played	3.07	2.90	3.82	3.04	.014
Net points won (%)	51.44	37.35	63.96	32.01	.010

[1] *Mann-Whitney U.*

Table III. Standardized coefficients from the discriminant analysis of the game statistics between winning and losing wheelchair tennis players in the 2012 Paralympics Games.

Game statistics variable	**Winner-Loser**
Break points won	-.35*
Points won on first serve (%)	-.35*
Break points won (%)	-.22
Receiving points won (%)	-.22
Points won on second serve (%)	-.21
Net points won	-.20
Total points won	-.17
Forced errors	.16
Total aces	-.13
Points won on first serve	-.12
Total winners	-.12
Net points played	-.12
Net points won (%)	-.11
Aces on first serve	-.11
Points played on second serve	.10
Unforced errors	.10
Aces on second serve	-.09
Break point opportunities	-.09
Returns on serve winners	-.08
Points played on serve	.07
Receiving points won	-.07
Backhand winners	-.07
First serve (%)	-.07
Double faults	.06
Points won on second serve	-.04
Receiving points played	.03
Points played on first serve	.03
Forehand winners	-.01
Eigenvalue	6.67
Wilks' Lambda	.13
Canonical Correlation	.93
Chi-square	406.67
Significance	.00
Reclassification	99.6%

** SC discriminant value ≥|.30|*

Discussion

The purpose of this study was to analyze the differences in wheelchair tennis game statistics between winning and losing players. The paper also provide values that could help to understand and analyse the game and could be used for coaches in the design of real game situation in practice. The results of this study show that winning players have better mastery of the serve situation, both in the number of aces per set, and points won on first and second serve. The percentage of first serves for the winner is similar to previous studies (Sanchez-Pay et al., 2013). These values are also similar to conventional tennis (Barnett el al., 2008; Brown & O'Donoghue, 2008). This indicates that the winners of the set have a better control of the serve situation than losing players, with better

control of effects, direction and hitting power in the serve, as happens in conventional tennis (Gillet, Leroy, Thouvarecq, & Stein, 2009).

Winning players have a significantly higher number of aces and lower number of double faults per set than losing players. These values are lower than those found in conventional tennis, (Cross & Pollard, 2011, Filipcic et al., 2008). This shows the difficulty for the wheelchair player to win points with the serve. Probably this is caused by wheelchair tennis players are in a lower position related conventional tennis (Sanz, 2003). Winning player seems to make safer serves, decreasing the number of double faults, so by playing safely the highest number of points are won. This information is useful to understand the game dynamic and can help to design a specific training and goals for this sport.

Regarding the return, winner had a significantly higher number of points than losers. These differences may be due to two aspects. Firstly, the loser does not dominate with his serve so does not gain winning points, and secondly, the winner makes more offensive returns with the intention to have the initiative. Values found in wheelchair tennis are higher than in conventional tennis (Filipcic et al., 2008; Katic et al., 2011). The cause of the differences between wheelchair tennis player and conventional tennis could be that the wheelchair or player injury does not allow to the player to use all the kinetic chain (lower body), the contact height is lower, and the server player after serving has to move quick from an static to dynamic situation (Sanz, 2003).
Winners convert more break points than the loser. The values found are higher than in conventional tennis (Filipcic et al., 2008; Katic et al., 2011). These differences, close to 20%, show that wheelchair tennis players are more likely to break serve than in conventional tennis. The causes, as are comment above, probably are related to the serve is less aggressive in wheelchair tennis than in conventional tennis.

Winning players are a more offensive players, almost double of winning returns and more winning shots than the loser. This could be because winning players have a better technical-tactical control in hitting (direction, distance, spin, and power) and/or competence with the wheelchair (recoveries, movement speed, and position). The ratio of winning shot per points is slightly better in wheelchair tennis than in conventional tennis (Filipcic et al., 2008), 1:2.56 and 1:2.75, respectively.

Considering together all the actions studied, two variables were found to represent best the difference between winning or losing, break points won and percentage of points won on first serve. Therefore, winning players have the capacity with their first serve to difficult returner´s action and

they are more aggressive or effective returning the serve, making lower number of errors during the match.

Future studies are need in wheelchair tennis to increase the knowledge about this sport. The kind of injury and physical capacities and skills may have an influence on the serve, concerning the impact point, the people with more stability could produce and hit the ball with a greater angle from the top (Sanz, 2003). Therefore, this relationship must be studied in order to know their relationship with technical-tactical actions and with the result of the set.

Wheelchair tennis is one of the adapted sports which has most grown competitively in the last decade. In search of professionalism, it is necessary to know what the differences are that determine the possibility to win or lose a match. This study concludes that the winner of a set has a greater mastery of the serve and return situation than the loser. Winner gets the greatest number of aces, percentage of points won on first and second serve, and return points and break points won. The winning wheelchair tennis player is a more offensive player (greater number of winning shots) and plays a safer game (fewer errors) than the loser. These data may contribute to a better understanding of this sport, where the results will help the coach to prepare and design training sessions according the real needs from the game situation.

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VI

Match activity and physiological load in wheelchair tennis players: a pilot study

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Match activity and physiological load in wheelchair tennis players: a pilot study

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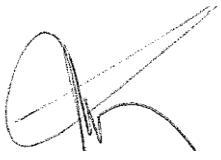
To whom it may concern,

I am pleased to inform you that the above mentioned manuscript has been accepted for publication in Spinal Cord.

Sincerely,



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Title: Match activity and physiological load in wheelchair tennis players: a pilot study.

Running title: Physiological load in wheelchair tennis players.

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Title: Match activity and physiological load in wheelchair tennis players: a pilot study

Study design: There is a lack of information about the physiological and psychological parameters in competition that show a comprehensive profile of the demands of the game situation.

Objective: The aim of the present study was to examine the activity patterns and physiological-perceptual responses (heart rate (HR), blood lactate concentrations (LA) and rate of perceived exertion (RPE), respectively) during singles wheelchair tennis (WT) matches.

Methods: A total of four WT players played three matches each. HR, LA and RPE were measured during each match. An activity pattern analysis was performed during all matches. Furthermore, LA and RPE were compared between service and return games.

Results: The results show a mean (SD) total match time of 69.04 (2.3) minutes, an effective playing time (EPT) of 17.65% (0.03%), a work:rest (W:R) time ratio of 1:4.6 (0.48) and a rally length of 7.04 (4.44) seconds. Most of the points end in three or fewer shots. The mean (SD) physiological load during the matches were: HR 124.25 (24.7) $b \cdot min^{1}$, $\%HR_{max}$ 66.31% (4.5%), LA 1.41 (0.43) mmol L^{-1} and RPE 12.45 (1.91). No significant differences were found in LA and RPE between service and return games ($p>0.05$).

Conclusions: In this descriptive study, match activity and physiological load in WT are described. Match activities are similar to conventional tennis, although the physiological load is lower. Service and return situations show similar physiological and perceptual responses. These results might be used to develop specific interval training protocols for a male WT player.

Key words: racquet sports, disability, competition, physiology.

INTRODUCTION

Wheelchair tennis (WT) is an adapted sport. Recent research indicates that a WT match is moderate to high in aerobic fitness.[1-5] Most of the studies related to the physiological demands of WT conclude that it is a healthy sport.[1,2,5]

WT players have 20 seconds to rest between points and 90 seconds between changes of side[6], the same rule as in conventional tennis. The total time of a singles WT match is between 50 and 80 minutes.[3-5,7,8] The intermittent nature of WT, with regular permitted rest times, means that the effective playing time is around 15–20% of the total time; this is equivalent to a ratio of W:R time of around 1:1 to 1:4.[4,7,9] The working time is represented by the rally duration which typically lasts between four to 10 seconds.[7,9,10]

The intermittent nature of the sport in a WT match means that the players have intermittent exercise bouts and a multitude of rest periods over a long duration.[11] In this sense, the heart rate (HR) is between 120–140 $b \cdot min^{1}$, with a 65–75% of maximum HR and a maximal oxygen uptake (VO_{2max}) estimation of between 50–68%.[1-5,12] There is not information related to other variables such as blood lactate concentration (LA) or rates of perceived exertion (RPE) in game situations.

The activity patterns and physiological demands of competition should be used in the exercises to improve the training sessions.[13] There is a lack of information about the LA and RPE in competition that shows a

comprehensive profile of the demands of the game situation. To know the physiology demands of the competition can help coaches and trainers to develop specific training programs in wheelchair tennis players. Furthermore, the aim of the present study is to examine the activity patterns and physiological-perceptual responses (HR, LA and RPE) during singles WT matches.

METHODS

Experimental approach to the problem

To determine the physiological demands of a singles WT match, a pilot study was designed and four advanced WT male players (n=4) were recruited. The variables analysed were used to describe the physiological responses in players and to know which physiological profile the WT players fitted.

Subjects

Four competitive WT male players (table 1) participated in this study. They were the four top ranked national players and in the top 110 International Tennis Federation (ITF) rankings at the time.

Table 1. Participant characteristics.

Subject	Gender	Age (years)	Height (m)	Weight (kg)	Nature of disability	Years since injury	Years practicing tennis
1	Male	19	1.65	53	Spine bifida*	19	6
2	Male	40	1.43	52	Osteogenesis imperfect	40	20
3	Male	46	1.80	70	Amputation**	27	13
4	Male	34	1.76	65	Amputation**	12	11
Mean	-	34.75	1.66	60.00	-	24.50	12.50
SD	-	11.58	0.17	8.91	-	12.01	5.80

SD = Standard Deviation. Spine bifida* = L5-S1. Amputation** = Complete amputation of right leg

All of the players were involved in regular tennis competitions at national and international levels. All players were highly trained with an average of five sessions a week, competing in about 10 tournaments a year. All the participants were right-handed tennis players. This study was approved by the ethics committee of the Royal Spanish Tennis Federation and all subjects provided a written informed consent before participation.

Procedure

Three experimental sessions with six total matches were conducted during a national WT team stage. In each session, two matches were played and they had 12 hours rest until the next session.

Each match started with a five minute standard warm up. Then, a single, best of three, tie break set match was played with new balls (Wilson US

Open). Play was according to the ITF rules for a clay court.[6] The time limits for changeovers and breaks between points were strictly enforced. The mean temperature during match play was 20–22ºC. All matches were finished in two sets.

Physiological measurements

Heart rate

All players were equipped with a Polar Team 2 (Polar, Finland) telemetry monitor to record HR before the warm-up. HR was recorded every second from the start to the end of the match. The data was analyzed with the Polar Team 2 software (Polar, Finland) indicating HR mean as a standard deviation.

All data were screened to ensure outliers (HR scores of 0 or > 220) were not present. HR_{max} was estimated for each participant (HR_{max} = 200 bpm - age). This equation has the same standard error (i.e., 12-15 bpm) than 220-age and has been used by different authors to be the most adapted equation by these population.[1,14,15] Estimation of HR_{max} enabled the determination of exercise intensity for each participant during each activity condition.

Blood lactate concentration

A drop of capillary blood was extracted from the earlobe with the intention of evaluating the changes in LA during the match (Lactate Pro, Japan). The

LA samples were taken during the changes of end in games 1, 3, 5, 7, etc., until the end of the match. A total of 55 samples were taken.

Rates of perceived exertion

RPE were obtained using the 15 category (scale from 6 to 20) Borg RPE scale[16]. All players were acquainted with the use of the scale. The RPE samples were taken during the changes of end in the games 1, 3, 5, 7, etc., until the end of the match. A total of 58 samples were taken.

Match analyses

Each match was filmed using a Panasonic HC-V700 (Panasonic-Japan) super wide angle camera. The videotapes were later replayed on a monitor for computerised recording of their activity patterns. The analyses of all six matches were performed by the same experienced researcher. Each match was monitored and recorded for subsequent analysis. Rallies duration (RD), and the shots per rally (SR) were encoded as has been done in other studies.[17-19] From these data, the following variables were calculated for the six matches analysed:

- RD, from the time the service player hit the ball at the first serve to the moment the point finished, in seconds;
- total time (TT), from the beginning of the first serve until the end of the last point of the match, in minutes, and

- shots per rally (SR), which was quantified as the number of balls hit by the players from the first service to the end of the point.

The following variables were then developed:

- effective playing time (EPT), which was determined by the sum of the single length of all rallies, in minutes;
- resting time (RT), which was determined by the sum of the break time between points (obtained by subtracting the start time of the point from the finish time of the previous point) in minutes;
- W:R, the ratio of duration of rallies to rest times;
- effective playing time percentage (EPT%), which was expressed as a percentage of the TT of play in a match and was determined by dividing the TT by the EPT, and
- resting time percentage (RT%), which was expressed as a percentage of the TT of play in a match and was determined by dividing the TT (from the beginning of the first rally until the end of the last rally) by the RT (sum of the break time between points).

A total of 24855 seconds were analyzed with 1983 shots distributed over 623 total points. Therefore the changes between changeovers were excluded from the RT.

Statistical Analyses

Data analysis was conducted using IBM SPSS version 20.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics (mean, SD) were obtained for all physiological-perceptual responses from participants and presented in the matches. Shapiro-Wilk and Levene tests were used to confirm the normality and homogeneity of variance, respectively. Independent-sample t tests were used to calculate differences between service and return games. The level of significance was set at $P \leq 0.05$.

RESULTS

Table 2 shows the match analysis and physiological and perceptual demands of the WT matches. In match analysis part, the variables describing the characteristics of the matches are shown. The total time was 69.04 ± 2.30 minutes, with a range of between 65.75 and 71.03 minutes. The effective playing time and resting time percentages show values between 15.30–20.50 and 77.50–84.70, respectively. Consequently the results shows the W:R ratio is 1:4.6 ± 0.84. The next part shows the physiological–perceptual demands of tennis match play for all matches analysed. The HR_{max} (200 - age) was 163.25 ± 11.55 $b \cdot min^{1}$. The HR average for all WT players was 124.25 ± 24.70 $b \cdot min^{1}$, (76.31 ± 4.50% of HR_{max}). Specifically, the player with spine bifida had a $\%HR_{max}$ lower (70.97±3.45) than amputee players (77.18±6.32) or player with osteogénesis imperfect (79.92±4.03).

The mean LA (n=55) was 1.41 ± 0.43 mmol·L^{-1} with a range between 1.10 to 1.98 mmol·L^{-1}. Moreover, the mean of the RPE value (n=58) was 12.45 ± 1.91 (somewhat hard).

Table 2. Mean, Standard Deviation (SD) and range for match analysis.

	Mean	SD	Range
Match analysis			
Total time (min)	69.04	2.30	65.75-71.03
Effective playing time (min)	12.19	2.06	10.20-15.97
Resting time (min)	56.86	2.66	50.95-60.12
Set duration (min)	34.52	5.39	25.62-43.73
Rally duration (s)	7.04	4.44	1.00-35.00
Effective playing time (%)	17.65	0.03	15.30-20.50
Resting time (%)	82.35	0.03	77.50-84.70
Strokes per rally	3.18	1.96	1.00-15.00
W : R	1 : 4.6	0.84	1 : 3.4-1 : 5.5
Physiological and perceptual demands			
RPE	12.45	1.91	8-16
LA	1.41	0.43	1.10-2.70
HR_{avg} (b·min^{1})	124.25	24.70	106.48 - 150.67
HR_{max} (b·min^{1})	163.25	11.55	152-179
$\%HR_{max}$ (b·min^{1})	76.31	4.50	70.97-80.15

Values are mean. SD = Standard Deviation; W:R = Work-to-Rest ratio. RPE: ratings of perceived exertion; LA: blood lactate concentration (mmol L^{-1}); HR_{avg} (b·min^{1}): heart rate average; HR_{max} (b·min^{1}): heart rate maximum teorical; $\%HR_{max}$ (b·min^{1}): percentage of heart rate average of HR_{max}.

Figure 1 shows the distribution of rallies duration during the matches. Most of the rallies (about 55%) lasted between one and six shots and 80% finished between one and nine shots.

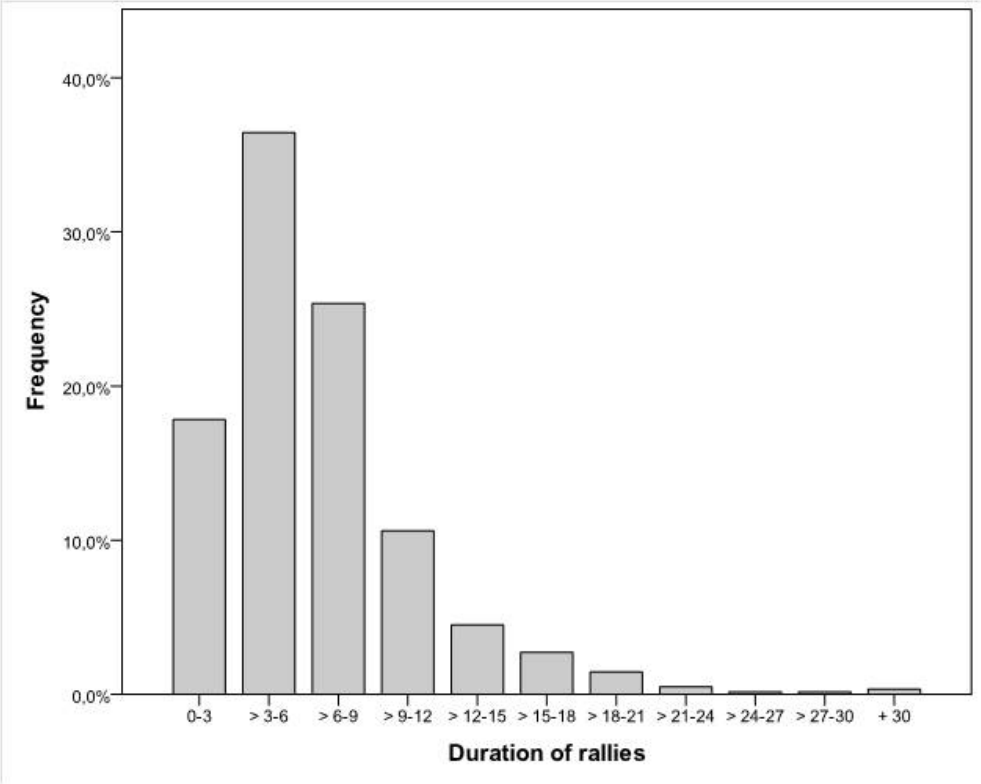

Figure 1. Distribution of the duration of rallies at three seconds.

Figure 2 displays the number of strokes performed per player during the 12 sets analysed. Most of the rallies (about 70%) finished between one and three shots and 92% lasted between one and six.

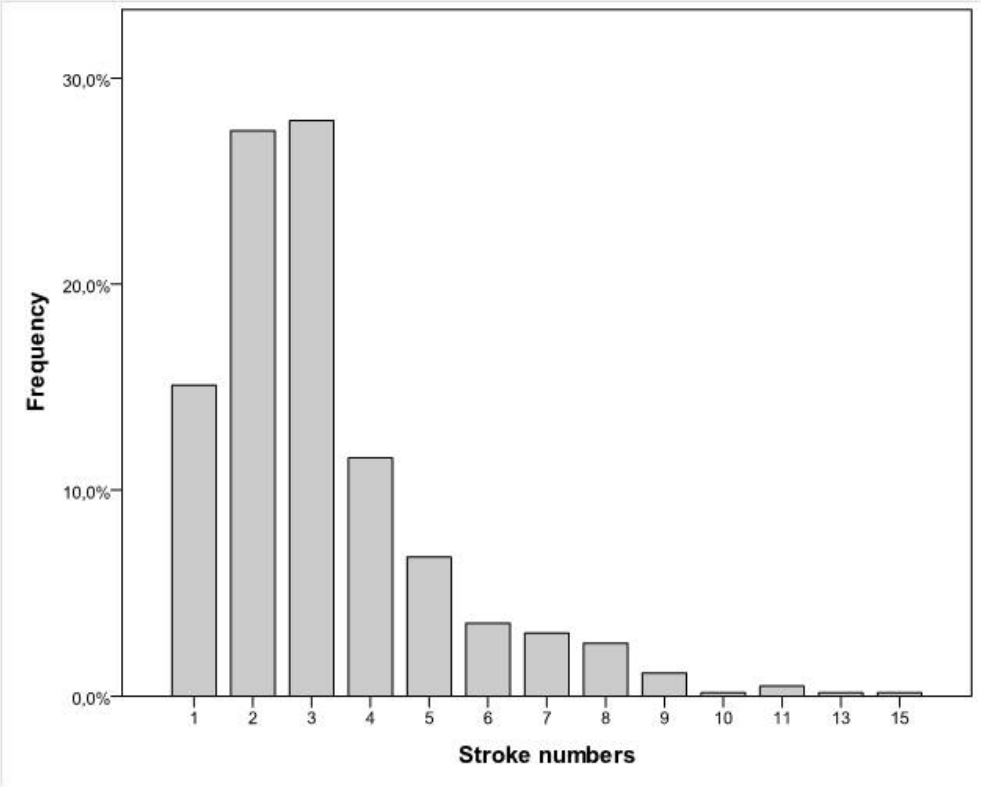

Figure 2. Distribution of the numbers of shots per point for all matches.

Furthermore, there are no significant differences in LA (p=0.879) after service games (1.42 $mmol \cdot L^{-1}$; n=26) and after receiving games (1.40 $mmol \cdot L^{-1}$; n=29). As in the LA, there are no significant differences in RPE (p=0.915) after service games (12.61; n=28) than after receiving games (12.62; n=29).

DISCUSSION

Control over a greater number of perceptual and physiological parameters can show a more accurate view of the needs of competition. To our knowledge, this is the first study to evaluate the physiological responses HR and LA with RPE and activity patterns in a wheelchair tennis (WT) male player. These parameters have shown the importance of taking into account the type of injury in wheelchair tennis players, to improve the specific training.

Match analysis

Data from the present study shows a total match time close to 70 minutes (Table 2). These values are similar to those in hard court play[3,4] but slightly lower than those recorded on clay courts[8] which obtained values higher than 80 minutes. The differences are close to 10 minutes; this may be due to differences with the selected sample.

The effective playing time was 12.19 ± 2.06 minutes (Table 2), representing 17.65% of the total time. This data is slightly higher than official matches on hard courts[4] and lower than unofficial matches on hard courts.[7,9] There are no studies on clay courts in relation to effective playing time, so we cannot compare between surfaces.

The percentage of effective playing time and resting time shows a W:R ratio of 1:4.6, which is similar to that recorded by other studies.[4,7] This reaffirms

the intermittent nature of this discipline, where there are higher values for resting time in comparison with effective playing time, allowing the players preparation time for the next point.

Regarding the rally duration, the data from this study shows a mean of 7.04 seconds per point (Table 2). The other data found in hard court, which focused on high-level international players, was higher than nine seconds.[9,10] Although points are observed with duration of up to 35 seconds (Table 2), almost 80% of them end within nine seconds (Figure 1). There is a tendency to a lower distribution of rally duration in recreational level.[7]

Although it has been concluded that points lasting 15 shots have a stroke per rally mean of 3.18, this is slightly higher at the Paralympics Games[10] which 3.00 strokes per rally, and lower than Veltmeijer *et al.*[9] with 4.00 strokes per rally, both on hard courts. Therefore, in spite of the differences in sample and playing surface, in this case the values are closer between the studies.

Physiological and perceptual demands

The WT players in the present study had a % HR_{max} of 76.31±4.50 in a game situation. The findings from the present study are therefore consistent with those, which have been reported in other WT studies of between 65–75% of maximum HR on hard courts.[1-5,12].

This study is the first to take samples of HR on clay courts, so we cannot compare our values with other studies on the same surface. The playing

surface has an implication for physiological player responses; in fact, conventional tennis studies show differences in HR between clay courts and hard court.[20] Our results are similar to other studies in WT on hard courts, and lower than the mean in conventional tennis on clay courts. [20] Therefore, more studies are necessary to evaluate the possible differences in the intensity of the game in relation to the playing surface.

In any case, the $\%HR_{max}$ is slightly higher than 75%, according to other studies in WT with high level players[3,5] and higher than with recreational level players (68–69%).[1,4] This may be because the high level players move faster and cover more distance per match than low level players.[5] No studies have been found in others adapted rackets sport. Compared with other studies in intermittent sports, ours results show $\%HR_{max}$ lower than wheelchair basketball[2,3] or wheelchair fencing[2]. This could be due a different in work:rest ratio during a game[3]. Specifically, $\%HR_{max}$ show lower values in a player with spine bifida than the others three players, with variation in percentage of 7.12%. This result is consistent with other studies that suggest that the physiological measures are lower as higher level of injury has the player.[21] In our case, we have too the same result concerning physiological measures, lower values of HR response, but our player have not a higher level of spinal cord injury, and according the pattern game of this player, very offensive, and with the length of the rallies and the number of strokes per point shorter, it seems reasonable to think that his lower heart

rate values are according his pattern activity profile. Although it is only one player with spine bifida, the differences in $\%HR_{max}$ should be considered in design of exercises and future research should compare the HR responses of a larger number of players with spinal cord injury (SCI) and players with amputations or non SCI. Nevertheless, WT is considered a sport of moderate to high intensity.[3-5] Although WT and conventional tennis players have the same rest time between points and games,[6] the $\%HR_{max}$ in WT match are lower than found in conventional tennis with high level players.[22] These differences due mainly the nature of each modality (use to upper members, ball speed or velocity of displacement...) and should be taken into account by coaches.

LA has often been used as an indicator of energy production from glycolytic processes during exercise.[19] The LA obtained in the present study was 1.41 ± 0.43 $mmol \cdot L^{-1}$. The LA values in WT previously were just from the training sessions[23] and were slightly higher than 2 $mmol \cdot L^{-1}$. The LA in the present study was lower than found in wheelchair basketball and wheelchair rugby in training session[23] or wheelchair basketball in game situation[24]. No studies have been found in adapted racket sport about LA in game situation. In comparison with conventional tennis players, ours data are lower than professional males[19] (3.8 ± 2.0) or pro-competition male players[20]. This reaffirms the view that the intensity is lower in WT than in conventional tennis and show to the coaches the differences between modalities. Despite

the fact that the intensity of play is high (75% HR_{max}), the rally duration (7.04 seconds) means there is not enough time for LA to be determined as a variable that limits performance. In fact, all data are related; WT is played at high intensity (75% HR_{max}), with high rest times (RT/EPT ratio is 1:4.6) and low concentrations of lactate (mean 1.41 $mmol \cdot L^{-1}$).

The RPE values in this study were 12.45 ± 1.91. These values are similar to those obtained in training sessions[23] (~12) and slightly lower at the end of each set[9] (12.8 ± 1.8 in the first and 13.2 ± 2.5 in the second set). Although the perceptual response to this activity profile is characterised by moderate RPE, there are values greater than 15 (Table 2), suggesting that there are periods of greater intensity throughout the match. There is more information about RPE in conventional tennis than WT and more studies are needed to better understand the functional behaviour of WT.

Service and return situation

Game play makes up about 90% of the points and will usually end up with five hits or less (Figure 2). The results show that, in the serve and return shots; there are more than 40% of the points. The data reflect that serving/returning scenarios are vital in WT. The physiological responses in conventional tennis are influenced by the playing situation (service vs return). In our study, there are no significant differences in RPE or lactate measurements in service and return play; the WT player shows similar

perceptual and physiological responses in both situations. We did not find any study in WT that takes this aspect into account. In conventional tennis, the service situation has significantly higher values in physiological responses than the returning situation.[19] The lack of differences in service and return situations could be due to a low number of strokes per rally (3.18), where most of the points end between two and three shots (Figure 2). Although the quality of each shot is not evaluated in our study, it could be said that it is important to carry out tasks in short duration with emphasis on effectiveness in a training session on court.

Our study had some limitations. An important limitation is the low number of subjects, so it difficult to draw strong conclusions about the activity pattern, and physiological and perceptual demands of male WT players on clay courts. Also, it is important to consider that the values obtained refer to a clay court surface in unofficial matches. It would be interesting to increase the number of subject groups.

In conclusion, WT is an intermittent sport, where the players are hitting the ball about every seven seconds. The work/rest relationship means the HR is between 106 and 150 beats per minute, which represents 70–80% of HR_{max} so it can be considered a moderate to high intensity sport. Further research is still necessary, since values depend on the kind of injury, playing surface and different competitive levels. These results might be used to develop

specific interval training protocols for a male WT player training in relation to this intensity according to the W:R ratio.

DATA ARCHIVING

There were no data to deposit.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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CONCLUSIONES

Con los resultados de la Tesis se pueden extraer las siguientes conclusiones:

a) Un partido de tenis en silla de ruedas de alto nivel tiene una duración en torno a 61 minutos con un tiempo real de juego del 20%, mostrando un ratio tiempo de trabajo : tiempo de descanso de 1:4 y una duración media del punto de 6.9 segundos con 3 golpes por punto.
b) La duración del punto y el número de botes por punto es mayor en partidos femeninos que en masculinos.
c) Las situaciones de break point no influyen en indicadores como duración del punto y número de golpes por punto, aunque el tiempo de descanso entre puntos es mayor en dicha situación.
d) La superficie del AO posee diferencias en la duración del set respecto al UO, siendo menor tanto en partidos masculinos como en femeninos. La superficie de juego parece afectar en mayor media a las variables relacionadas con el saque en el TSR masculino y a las variables relacionadas con el resto en el TSR femenino.
e) Los indicadores de rendimiento que marcan diferencia entre ganar y perder, tanto en tenistas masculinos como femeninos en una especialidad como el tenis en silla de ruedas, son los puntos de break ganados y los puntos ganados de primer saque.
f) Las demandas psicofisiológicas del jugador de tenis en silla de ruedas muestran una FC de 124 $lat \cdot min^{-1}$, una concentración de lactato sanguíneo de 1.41 $mmol \cdot L^{-1}$ y un RPE de 12.45. La acción de saque o resto no produce respuestas psicofisiológicas diferentes en los jugadores.